RIVER INTRODUCTION INTO MAUREPAS SWAMP

1-D (SWMM) MODEL STUDY

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OBJECTIVE

The objectives of the 1-D Model in the subject project are two-fold. First, the model will provide flow input into a 2-D Model. The second objective is to evaluate the impact of the Diversion Project on the drainage system of St. John the Baptist Parish. In the subject project, Mississippi River water will be diverted into the Maurepas swamp. Rainfall runoff on the East Bank of St. John Parish flows into these same wetlands. The 1-D Model will estimate the effects on the existing drainage system when the Diversion Project is in operation.

The 2-D Model of the Maurepas swamp models how the diversion water is routed throughout the Maurepas Swamp, so as to provide a residence time for the water that will allow the nutrients in the water to be absorbed into the swamp biomass. One output from the 2-D Model will be Water Surface Elevation (WSE) curves at the various output points of the 1-D Model. For this Report these WSE's are referred to as "Tides". Since the 2-D Model needs input from the 1-D Model, in terms of flows into the swamp and the 1-D Model needs input from the 2-D Model, in terms of Tides, there must be an iterative procedure to arrive at the final solution. The result of this two-fold evaluation is a Response Analysis showing how the existing St. John Parish drainage system will respond to the Diversion Project under a wide range of rainfall and tide conditions.

SUMMARY

A schematic diagram of the 1-D Model, from SWMM, is shown in Figure 1. It is composed of numbered Nodes and Links. The flow of water is from south to north, where a number of outfalls are located. These are labeled Marsh1-3 (which combines the Hope Canal flows (Marsh 1, 2 & 3) into one outfall) through Marsh 18. One outfall, (Reserve Relief Canal) RRC is at Lake Maurepas (Lake M). The Airport pumping station is labeled Airport PS. A second pumping station is at Belle Point and is called Belle PT. The pumping stations are not affected by tides. Figures 2 shows the SWMM Subcatchment areas used in the Model. Subcatchments are discussed in the *Methodology* section, below. The 1-D Model also includes 23 storage areas: (SA-A through SA-W) (see Figure 3) which were designed to model flooding in the Parish. The network of links (representing canals) shown in Figure 1 is overlain with a second network of overland channels leading to the storage areas. When a given canal in the primary system becomes surcharged with water (i.e. floods) this excess water is routed through the overland channels to an appropriate storage area. During a significant rainfall event, canals will surcharge and excess water will accumulate in the storage areas, representing flooding.

The proposed project will eliminate gravity flows from the Garyville area into Hope Canal, because the Diversion Project would modify Hope Canal and utilize it as the diversion channel. A pumping station would need to be placed in Hope Canal north of Airline Drive to lift gravity drainage into the diversion channel. This was simulated in SWMM by setting the Outfall Control Type at Marsh 1-3 to "Free Outfall", assuming that the suction bay of the new lift station could be kept low enough to provide free outfall conditions for the Garyville drainage system. The 1-D study showed that converting the Garyville outfall from tidally influenced gravity

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drainage to pumped flow, by virtue of the Diversion Project, will not affect the response characteristics of the Parish drainage system. This can be seen in Figure 4, which compares the total flow of the drainage system, with and without the Diversion, for the ten-year and one hundred-year storms and shows that the Diversion, itself, will not change the response characteristics of the drainage system.

Before attempting to establish the characteristics of how the drainage system responds to increasing Tide in the Maurepas swamp, the system was calibrated. Suitable historic storms were found and run through the system. Figure 5 shows the location of the three rain gauges and four stage gauges used in the study. The calibration procedure is described below and detailed in Appendix A; the results are shown in Figures 6 through 9. Following calibration of the system, preliminary 10-year and 100-year Performance Curves were developed for each outfall point, showing Flow vs Tide. These curves provided the interface with the 2-D model for the 10-year and 100-year storms. Performance Curves for the outfall points are presented in Appendix B.

In general, as Tides increase, the ability of streams to carry water to the marsh decreases; therefore, storage area WSE will increase as Tides increase, although the effect varies from storage area to storage area. Storage areas nearest the Maurepas swamp will be impacted to a greater extent than those farther away. In order to better visualize the effect of increased tides on storage area WSE, the storage areas were grouped into three Tiers: Northern Tier, Middle Tier and Southern Tier. Some storage areas in the Northern Tier (near the swamp) showed an increase in WSE with increased Tide in the swamp, but others were not affected by Tides at all. The response in the Middle Tier was similar to that in the Northern Tier, except that the increase in WSE was less, where it occurred. The Southern Tier of storage areas showed no response to Tides. The results are shown in Figures 10 through 12 for the 10-year & 100-year storms. Contours of storage areas are presented in Appendix C.

METHODOLOGY

In order to determine the effect of the Diversion Project on St. John Parish drainage, the drainage system has been modeled using the SWMM (Storm Water Management Model) program. Two computational "Blocks" of SWMM were utilized in the Model: the Runoff Block and the Extran Block. The Runoff Block inputs a rainfall hyetograph, representing historic or design rainfall rates (in/hour) over time, into the various Subcatchments, representing the land upon which the rainfall occurs, and produces runoff hydrographs of flow (cfs or cubic feet per second) versus time at each Node with one or more Subcatchments associated with it. The Extran Block models the network of conveyance channels (Links) which routes hydrographs produced by the Runoff Block to the various Nodes in the network through channels and eventually to the outfall points of the system, adding flows for each time step as the flow is routed downstream. To accomplish this, the program computes water surface elevations (WSE's) at each Node for each time step. The WSE's are then used to compute hydraulic profiles used in computing flows through the channels using the Manning formula. The output for SWMM consists of Stage Hydrographs at each Node and Flow Hydrographs at each Link. The Model constructed to represent this portion of St. John the Baptist Parish consisted of 1659 Nodes, 1949 Links, 1579 Overland Channels and 23 Storage Areas. Visual SWMM by CAiCE was utilized to run the SWMM program on the personal computer.

SWMM Runoff Block Hydrology

The SWMM Model Runoff block uses several hydrologic subroutines; one of which is the standard SWMM Runoff routine, utilizing the input parameters of Subcatchment Area (Ac), % Imperviousness, Infiltration Rate, and Subcatchment Width & Slope. The Runoff routine is most suited for small urban areas. A second type of hydrologic procedure which the SWMM Runoff block offers is the Soil Conservation Service, or SCS, methodology. This methodology utilizes parameters of Subcatchment Area and Curve Number, CN. Standard Curve Numbers have been developed empirically, by the Soil Conservation Service, for each soil type and ground cover. The CN represents the infiltration rate of rainwater into each type of soil (and ground cover) over time. The SCS methodology is most suited for large, rural areas.

Using high resolution aerial photography, the subject project area was divided into Subcatchment areas (see Figure 2). Acreages of Subcatchment areas were obtained using a CAD program. Subcatchment widths and slopes were obtained from the aerial maps. Values of Percent Imperviousness for the various Subcatchments were estimated from aerial maps and field investigations (see below). The Green-Ampt method of modeling infiltration is best suited for the type of soils and ground cover in the Model area and was used. SCS CN's were estimated using soil maps of St. John Parish and the SCS *National Engineering Handbook Section 4: Hydrology*. The lower-lying areas of the St. John Parish drainage system north of Airline Drive are fairly flat and rural, consisting of agricultural areas, pasture land and wooded areas and were modeled using the SCS method of the SWMM Runoff block. Much of the area south of Airline Dr. is rural and was modeled using the SCS method. Only the urban areas near the Mississippi River were modeled using the usual Runoff Block methodology.

The following values for % Imperviousness were used in subcatchment areas:

Older residential (low DCIA (Directly Connected Impervious Area))	30%
Newer residential (high DCIA)	40%
Industrial	45%

SWMM Extran Block Hydraulics

The SWMM Extran block consists of Nodes and Links arranged so as to simulate the geometrical alignment of the drainage network. This SWMM investigation originated with an Extran model from a previous project developed by another engineering consultant, which had been previously modified by URS by adding overland channels and storage areas to simulate flooding. The first step in recreating the Extran network for this project was to examine all the canal cross sections and culverts. All canal cross sections were plotted out and examined for obvious errors. Several errors were found and corrected. Canal lengths and connectivity in the model were checked by electronic scaling using an ArcIMS website image prepared by URS to hold and display all geo-hydrologic data for the project. The SWMM Model was run and examined for areas of numeric instability. Numeric instability can be difficult to eliminate, but efforts were made to reduce or eliminate it in these areas and the final product ran with only

minor instabilities. Field surveys were completed for the subject project to verify cross sections and culvert dimensions at spot locations (see *Topographic and Bathymetric Survey Report*, URS Corporation, 2005). All of these were examined and adjustments in the Model were made where necessary.

Storage Areas

The subject area was divided into Storage Areas (SA's): naturally occurring surface regions, which being bounded by canals, roadways or other features, would tend to retain excess water. Figure 3 shows the boundaries of the Storage Areas used in the 1-D Model. Each Storage Area was evaluated as to its reasonableness and then analyzed using LiDAR imagery obtained from an LSU website. The LiDAR imagery was processed by the *Land Development Desktop* program, producing 1-foot contours. Each Storage Area was isolated and printed out, assigning various colors for the various contours. The low point elevation was also established for each Storage Area. The *Land Development Desktop* program computed the area in acres for each contour and the accumulated volume in acre-feet. The details of each Storage Area can be found in Appendix C. Curves of Area (acres) vs Depth (ft.) were prepared from these data for each Storage Area and input into SWMM. Each SA (Storage Area) in SWMM was connected to the network of overland flow channels in EXTRAN by one or more links. In order to model the slow draining of the Storage Areas following a rainfall event, each Storage Area was provided with a small diameter (usually 1 foot) one-way flow pipe from the SA low point back to a nearby canal. In this way surcharging water from the primary drainage system could be captured in Storage Areas and distributed, both horizontally and vertically, according to the geometry of the Storage Areas and then allowed to drain back into the system. The resulting Storage Area hydrographs showed the depth of flooding that would be expected in different parts of the study area for a given storm event. What we were able to show with the storage area analysis was the effect of increased water surface elevation in the Maurepas Swamp (Tide) on channel output and on flooding in the drainage system. As the swamp elevation increases the system showed a decrease in channel outflow and an increase in flooding in the system (See Response Analysis, below).

CALIBRATION

In the process of calibration, an historical storm is processed through the Model and the results at selected Nodes compared with readings from stage gauges placed in the various canals at strategic locations. See Figure 5 for Stage Gauge locations used in this study. Both peak WSE and general shape of the outfall hydrograph are considered in calibrating the Model. The calibration of the 1-D model can, and should, be done independently of the 2-D model. Model calibration was performed using the following procedure:

- Select a suitable storm from rain gauge records in the area
- Prepare a rainfall hyetograph to represent the storm
- Prepare tidal history for the same period from gauges placed in the Maurepas swamp
- Run the Runoff block with historical rainfall and the Extran block with corresponding tidal histories
- Compare the SWMM Extran output hydrographs at locations where gauges were present with the gauge data.
- Adjust Model (Runoff parameters and/or Extran roughness coefficients), re-run SWMM and repeat as necessary to obtain desired results

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Select suitable storm. A suitable calibration storm should have enough rainfall to produce a noticeable rise in the system canals, but not enough to produce surcharging (flooding) in the system. If there is surcharging in system culverts, the Model will be very difficult to calibrate, because the downstream hydrographs are being controlled by upstream culvert hydraulics and not the hydrologic parameters of the Subcatchments. Examination of rainfall and gauge records, for the time period in which the gauges were in place, yielded one rainfall event which involved enough rainfall to increase flows in the canals but not so much as to cause surcharging. This event began at about 8 AM on February 10, 2004 and lasted until about 5 PM February 14, 2004 and produced about 3 inches of rainfall. A storm suitable for the Verification storm was also found. It began on about 3:30 AM, February 23, 2004 and extended to about noon, February 25, 2004.

Prepare Rainfall Hyetograph. Three hourly Rainfall gauges (Amite River at French Settlement, Amite River at Maurepas and New River at Sorrento) were used to produce the Calibration Hyetograph. These gauges were all located northwest of the project area and all about the same distance from the area (See Figure 5). No hourly gauge was inside the study area. The hourly records for the three gauges were averaged to produce the Hyetograph for the rainfall event. All three gauges were given equal weight because there was no reason to give more weight to one gauge over another. Daily totals were compared with a daily rainfall gauge at the Marathon plant inside the study area. See Table 3 for Marathon gauge daily rainfall totals for February, 2004. The Marathon gauge readings appeared to be one day behind the hourly rain gauges. The reason for this was that the Marathon gauge was read once a day from about 6:30 to 7:30 AM and that total was assigned to the day it was read; however, the rainfall measured in the gauge was for the previous 24 hour day. The average total rainfall for the three rain gauges for the Calibration Storm period was 2.86 inches. The total rainfall at the Marathon gauge for the same period was 3.00 inches. The difference is 4.67% of the total. The Verification Storm had a total rainfall, averaged from the three rain gauges, of 2.72 inches, compared with the total for the same period as recorded at the Marathon gauge of 3.86 inches (29.5% difference). Whereas the comparison of total rainfall for the Calibration Storm was good, the daily distribution of rainfall for the average daily totals was different from the Marathon daily gauge. The Calibration storm and the Verification storm were run through the Model. The results are described below. After modifying the hourly rainfall averages to prepare rainfall hyetographs which would reflect the daily totals at the Marathon gauge, both the Calibration and Verification storms were run through the Model and the results compared to the Stage Gauges placed in the field. The results for both sets of runs were examined quantitatively and showed that the unmodified rainfall hyetographs produced results closer to the stage gauge records than did the modified rainfall hyetographs. Therefore, the average hourly rainfall from the three rainfall gauges was not modified to reflect the Marathon daily gauge readings when preparing Calibration and Verification rainfall hyetographs used in this study. The methodology is further explained in Appendix A.

Datum. Several Primary Control Networks, utilizing NAVD-88 Datum, are in effect in the project area: The original SWMM Model used a particular bench mark based on NAVD 88; Louisiana State University (LSU), which placed and retrieved data from the project field gauges, used another vertical control and the Department of Natural Resources (DNR), which sponsored the project, used a different vertical control. URS adjusted LSU provided gauge data to be compatible with DNR datum. Field surveys done for this project were completed using DNR datum. Twelve survey elevations at 6 hard structures (culvert headwalls, etc.) along Airline Dr.

were compared with similar points provided in the SWMM data base and the average difference was found to be negligible (.10 feet, see Table 1). Therefore, the SWMM Model was found to be fully compatible with DNR datum. The use of Vertical Datums in this project is more completely described in *Topographic and Bathymetric Survey Report*, URS Corporation, 2005.

Tide History. Three gauges (S-5, S-3 and S-24) were used to provide a tidal history for the Model. Gauge S-5 is on Hope Canal, north of Airline Dr. Gauge S-3 in on Reserve Relief Canal near lake Maurepas and S-24 is on Reserve Relief Canal north of Airline Dr. (See Figure 5 for location of gauges). The gauge record from Gauge S-5 was input into the SWMM Model as *User Stage History* at all outflow points west of the Reserve Relief Canal and the gauge record from Gauge S-24 was input as *User Stage History* at all outflow points east of the Reserve Relief Canal. Gauge S-3 was used as *User Stage History* at the *Lake M* outflow point (Reserve Relief Canal discharge into Lake Maurepas).

Gauge Data. Gauge data from Gauge S-27, Hope Canal a few hundred feet south of Airline Dr. and S-24, Reserve Relief Canal, just north of Airline Dr. were used to calibrate the Model by comparing the hydrographs produced from plotting the gauge data over time with SWMM hydrographs at Node 2E-273 (Hope Canal) and Node 939 (Reserve Relief Canal), respectively. Since Gauge S-24 is in Reserve Relief Canal it was used as the calibration gauge in that canal as well as a Tide gauge, as explained above. The tide history (*User Stage History*) for Reserve Relief Canal was taken from Gauge S-3 at the far north end, near Lake Maurepas, but for calibration purposes, Gauge S-24 was used to compare with SWMM Node 939.

Calibration Results. The SWMM Runoff block and Extran block were run with the Calibration Storm hyetograph and Tidal History for February 10-14 and the results compared: Node 2E-273 with gauge S-27 (Hope Canal) and Node 939 with gauge S-24 (Reserve Relief Canal). The results are shown in Figures 6 and 7.

In the calibration process, assumed general parameters are adjusted to allow the Model results to better reflect the measured data. The various Runoff Parameters, discussed above, were assumed from previous experience with the SWMM program and with the study area being modeled. Channel roughness factors are the only general Extran parameters which can be modified in the calibration process. The Manning's roughness factors in the various outflow channels had been adjusted in calibrating the Model for the previous project, so they were not readjusted. After rerunning the SWMM Model for the Calibration and Verification storms, the simulated peak water surface elevations at Hope Canal and Reserve Relief Canal were compared to the gauge records in the same general locations.

The results are as follows: Hope Canal: SWMM Node 2E-273 maximum elevation was 2.27, compared with Gauge S-27 peak elevation was 2.34, a difference of (-)0.07 feet. The shapes of the two hydrographs were similar (See Figure 6). The primary SWMM peak lags behind the Gauge peak by 2 hrs and 43 minutes. The SWMM hydrograph showed a secondary peak about six hours after the primary peak. The same general shape can be seen in the Gauge S-27 data; however, the secondary peak in the SWMM Model is greater than the similar peak in Gauge S-27. Since the primary SWMM peak is somewhat lower than that of the Gauge peak, but the secondary SWMM peak is greater than the observed Gauge peak, the differences are not systematic and no adjustment of the general assumed parameters could be made to further fine-

tune the Model. The timing of the peaks is a question, but the results of the Reserve Relief Canal Calibration Run indicate the answer. (See below)

At the Reserve Relief Canal calibration point, the hydrograph from the SWMM Node 939 was compared with Gauge S-24. The results are shown in Figure 7. The Gauge data from S-24 in the Reserve Relief Canal showed a great deal of variability, probably due to wave action in the channel. Thus, the average peak was judged to be about 1.61. The peak WSE at Node 939 is 1.56 feet, a difference of (-)0.05 feet. The timing of the upswing of Node 939 agrees well with Gauge S-24, but the falling leg of the curve occurs in Node 939 a little bit sooner than at Gauge S-24. The mathematical peak of the SWMM peak leads the Gauge peak by 4 hours. Because the SWMM peak at Hope Canal lagged the Gauge peak but led the Gauge peak at the Reserve Relief Canal, it is clear that the timing issue is not systematic; that is, no general calibration of the SWMM Model could adjust the timing of the peaks to better fit the field data. All in all, the match is satisfactory. The results of the Calibration and Verification peak water surface elevations are summarized in Table 2.

VERIFICATION

In order to more completely assess the 1-D Model, a Verification Storm was run through it. A second rainfall event occurred during February, 2004, which was the type of storm which could be used in the calibration process. It began at about 3:30 am on February 23 with an initial peak and continued during the 24th with a secondary peak on the 25th, and ending about noon on February 25. The distribution of rainfall was fairly uniform among the three regional recording stations used for the study, with a peak on the 23rd and another peak on the 25th; however, the intensities varied widely between the various stations. This indicated the spotty nature of the rainfall event. Evidently, this event was not as uniform as the Calibration Storm. The rainfall records at the recording stations were averaged for each time step. Comparing the average total with the total at the Marathon rain gauge showed that the average hourly rainfall could be used as the rainfall hyetograph for this event, although it would not be ideal.

The results of the Verification Storm are shown in Figures 8 & 9, which compares the SWMM output at Node 2E-273 with the record at Gauge S-27 (Hope Canal), and Node 939 with Gauge S-27 (Reserve Relief Canal), respectively. The shape of the curves in Figure 8 match fairly well, except for a peak in the Gauge S-27 record early on February 24, which does not show up in the SWMM report. As was stated, above, this storm was not very uniform throughout the area and evidently there was a localized shower in the Hope canal watershed on February 24 which was not recorded by any of the regional rain gauges. The SWMM report at Node 2E-273 for the initial peak on the 23rd was higher than Gauge S-27 by about 0.11 feet with no difference in the timing of the peak; and the secondary peak on the 25th was lower than Gauge S-27 by about 0.06 feet with a one hour difference in the timing of the peak. These show a good match to the observed data, except for the localized peak at Hope Canal on the 24th. Note that the SWMM peak at Hope Canal (Node 2E-273) was less than the peak in the Gauge S-27 record in the Calibration Run and more than the Gauge S-27 peak in the Verification Run (Figure 8). The secondary peak was greater in the Calibration Run and less in the Verification Run. The SWMM peak for the Reserve Relief Canal (Node 939) was less than that for Gauge S-24, but indistinguishable from the record of Gauge S-24 in the Verification period (see Figure 9). The timing issue that was seen in the Calibration Run was not repeated in the Verification Run. Considered together, the variation in the results of the Calibration and Verification Runs appears

to be random and not systematic. For this reason the SWMM Model was considered to be calibrated with no further adjustments of any of the Runoff or Extran hydrologic or hydraulic parameters. The calibration procedure is further detailed in Appendix A.

The results of the Calibration and Verification peak water surface elevations are summarized in Table 2. The total difference in peak water surface elevation for Calibration and Verification at two points is .03 feet.

BASELINE SCENARIOS

Once the SWMM Model was calibrated, it was used to analyze the response of the drainage system for a wide range of tidal conditions.

The following SWMM runs were made:

5 year return frequency with moderate lake conditions (Tide = 0.5, 1.0, 1.5, 2.0, 2.25)
10 year return frequency with moderate lake conditions (Tide = 0.5, 1.0, 1.5, 2.0, 2.25)
50 year return frequency with moderate lake conditions (Tide = 1.0)
100 year return frequency with moderate lake conditions (Tide = 1.0)

RESPONSE ANALYSIS

The response of the drainage system under investigation is such that as the Tide in the swamp increases, flows in the various discharge channels decrease and surcharging into Storage Areas increases. The cause of increased Tide does not matter. The response of the drainage system will be the same whether the increased Tide comes from natural forces or from the proposed diversion. The only difference in the drainage system that the diversion will have is that in the system with the diversion in place, the tidal outfall at Hope Canal will be replaced with a pumping station (free outfall). Performance Curves of Flow vs Tide for the 18 outfall points for the Model were prepared and are shown in Appendix B for the 10-year & 100-year storm events. These curves were given to the 2-D team to estimate flows from the drainage system into the 2-D Model for various design storms. Figure 4 shows the total drainage flow from the system verses Tide for the 10 year and 100 year storms and for "with" and "without" the Diversion (i.e. with and without the Garyville Pumping Station). This shows that the total output from the drainage system is affected by Tide, but unaffected by the Diversion itself. That is, the required pumping station at Hope Canal will not change the response characteristics of the drainage system.

Flooding is represented by water accumulating in the Storage Areas. To understand the effect of Tide on flooding, curves of Storage Area Depth vs Tide for the three Tiers of Storage Areas were prepared: Northern Tier, Middle Tier and Southern Tier. They are shown in Figures 10 through 12 for the 10-year storm in the calibrated Model. In general, as Tide increased the water surface elevation in the Storage Areas increased; however, the increase was greater in some Storage Areas and less in others. Some Storage Areas, due to the geometry of the Storage Area and the connectivity to the drainage system, showed no increase in water surface elevation due to increased Tide. In general, the Storage Areas nearest the Swamp (Northern Tier, Figure 10) showed the greatest response to tides and those farthest away from the Swamp (Southern Tier, Figure 12) showed the least response to tides.

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1-D 2-D INTERFACE

The 2-D Model was calibrated using four extended periods of time in which both rainfall and tidal variations occurred. Two such Validation periods lasted 30 days and two lasted 61 days. Rainfall data and tidal data were gathered, processed and input into SWMM. The Model was run and outflow from the discharge Nodes were exported into an Excel spreadsheets to be input into the 2-D Model. The results of this phase and additional phases of investigation will be contained in future reports.

TABLES

TABLE 1: COMPARISON OF SWMM ELEVATIONS WITH PROJECT ELEVATIONS

Structure	Location	SWMM		Project Survey		SWMM
		Link	Elevation (ft.)	Number	Elevation (ft.)	- Survey
RC Box	Hope Canal, north of Airline Dr.	3E-279	0.54	1472	-0.50	1.04
RC Box	Hope Canal, south of Airline Dr.	3E-277	0.41	1443	-0.50	0.91
RCP	Marsh 8, north of Airline Dr.	3E-245	0.60	1245	0.3	0.30
RCP	Marsh 8, south of Airline Dr.	3E-250	0.97	1202	0.9	0.07
RCP	San Francisco Canal N. of Airline	3E-42	-1.69	1103	-0.4	-1.29
RCP	San Francisco Canal S. of Airline	3E-36	-1.66	1096	-0.2	-1.46
RCP	San Francisco Canal N. of Airline	3E-43	-1.50	1104	-0.7	-0.80
Jt. Box	Marathon Rd. Top of Box	3E-247	6.10	1226	6.4	-0.30
CMP	Double Pipe across Marathon	3E-251	0.97	1200	0.4	0.57
	Double Pipe across Marathon	3E-251	1.32	1201	0.9	0.42
CMP	Double Pipe from south at Marathon	3E-249	1.87	1224	0.9	0.97
	Double Pipe from south at Marathon	3E-249	1.87	1225	2.2	-0.33
				Arithmatic Sum of Differences		0.10

TABLE 2: CALIBRATION AND VERIFICATION RESULTS

PEAK WATER SURFACE ELEVATIONS

	Hope Canal (ft.)			Reserve Relief Canal (ft.)		
	2E-273	S-27	Delta	939	S-24	Delta
Calibration	2.27	2.34	(-)0.07	1.56	1.63	(-)0.07
Verification	2.34	2.23	(+).11	1.93	1.86	(+).06
Sum =			(+)0.04			(-)0.01
Total Sum =				(+)0.03		

TABLE 3: MARATHON DAILY GAUGE READINGS
MARATHON OIL CO.
RAINFALL   MONTH February, 2004

TIME	DATE	RAINFALL (inches)
6:30 AM	2/1/2004	0.02
6:36 AM	2/2/2004	0.00
6:30 AM	2/3/2004	0.26
6:29 AM	2/4/2004	0.00
7:37 AM	2/5/2004	0.48
6:17 AM	2/6/2004	1.00
7:16 AM	2/7/2004	0.00
7:10 AM	2/8/2004	0.00
6:30 AM	2/9/2004	0.00
6:37 AM	2/10/2004	0.00
6:19 AM	2/11/2004	1.52
6:39 AM	2/12/2004	0.94
6:20 AM	2/13/2004	0.02
6:40 AM	2/14/2004	0.20
6:45 AM	2/15/2004	0.32
7:00 AM	2/16/2004	0.00
6:29 AM	2/17/2004	0.00
6:26 AM	2/18/2004	0.00
6:27 AM	2/19/2004	0.00
6:32 AM	2/20/2004	0.00
6:45 AM	2/21/2004	0.00
7:00 AM	2/22/2004	0.00
6:47 AM	2/23/2004	0.23
6:20 AM	2/24/2004	2.72
6:22 AM	2/25/2004	0.75
6:51 AM	2/26/2004	0.15
6:26 AM	2/27/2004	0.01
6:30 AM	2/28/2004	0.00
6:30 AM	2/29/2004	0.00

TOTAL _____ 8.62

Daily Rainfall (Maximum)   2.72

Daily Rainfall (Average)   0.297

FIGURES

LEGEND

R91 ⊙	NODE	
2629 →	LINK	
△ SA-V	STORAGE AREA	
MARSH 11 ⊙	OUTFALL NODE	

URS

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MISSISSIPPI RIVER DIVERSION INTO MAUREPAS SWAMP	FIGURE NO. 1
1-D (SWMM) MODEL PLAN VIEW	PROJECT NO.

DESIGNED BY:
DRAWN BY:
CHECKED BY:
REVIEWED BY:
DATE: 11-23-05

NO.	DATE	REVISION	BY

MISSISSIPPI RIVER DIVERSION
INTO MAUREPAS SWAMP

1-D (SWMM) MODEL
SUBCATCHMENT AREAS

FIGURE NO.
2

PROJECT NO.

DESIGNED BY:
DRAWN BY:
CHECKED BY:
REVIEWED BY:

DATE: 2-16-06

BY

NO. DATE   REVISION

N

MISSISSIPPI RIVER DIVERSION
INTO MAUREPAS SWAMP

1-D (SWMM) MODEL
STORAGE AREAS

| FIGURE NO. | 3 |
| PROJECT NO. | |

	BY
DESIGNED BY:	
DRAWN BY:	
CHECKED BY:	
REVIEWED BY:	
DATE:	11-23-05

NO.	DATE	REVISION

Storage area labels: SA-G, SA-Q, SA-P, SA-O, SA-W, SA-F, SA-E, SA-N, SA-V, SA-D, SA-L, SA-M, SA-U, SA-C, SA-K, SA-J, SA-B, SA-I, SA-S, SA-A, SA-H, SA-R

Figure 4: Total Peak Flow From System vs. Tide

Legend:
- Total 10 Yr. Flow Without Pump Station
- Total 10 Yr. Flow With Pump Station
- Total 100 Yr. Flow Without Pump Station
- Total 100 Yr. Flow With Pump Station

Y-axis: Total Peak Flow (cfs) — 1500 to 2500

X-axis: Tide (ft.) — 0.0 to 2.5
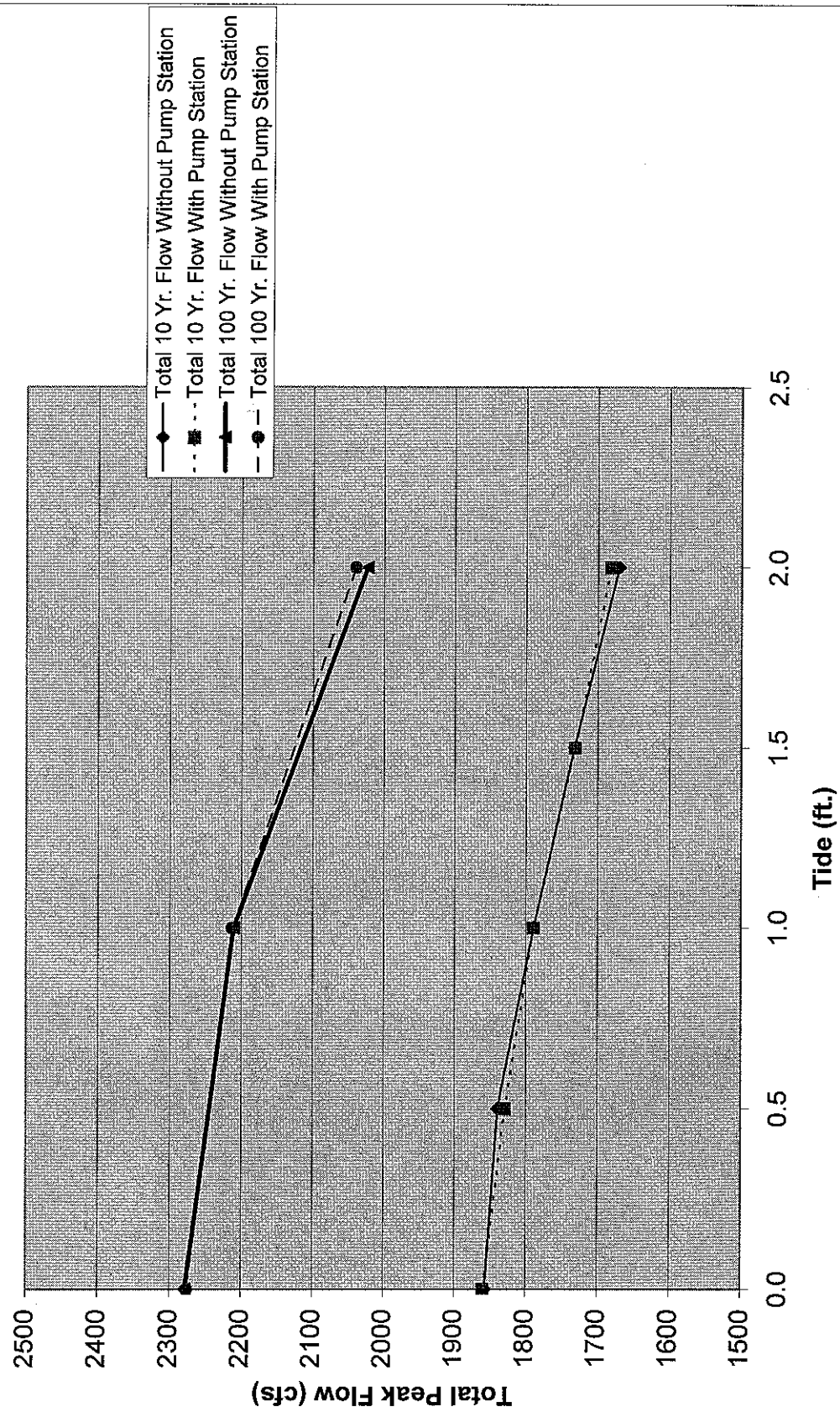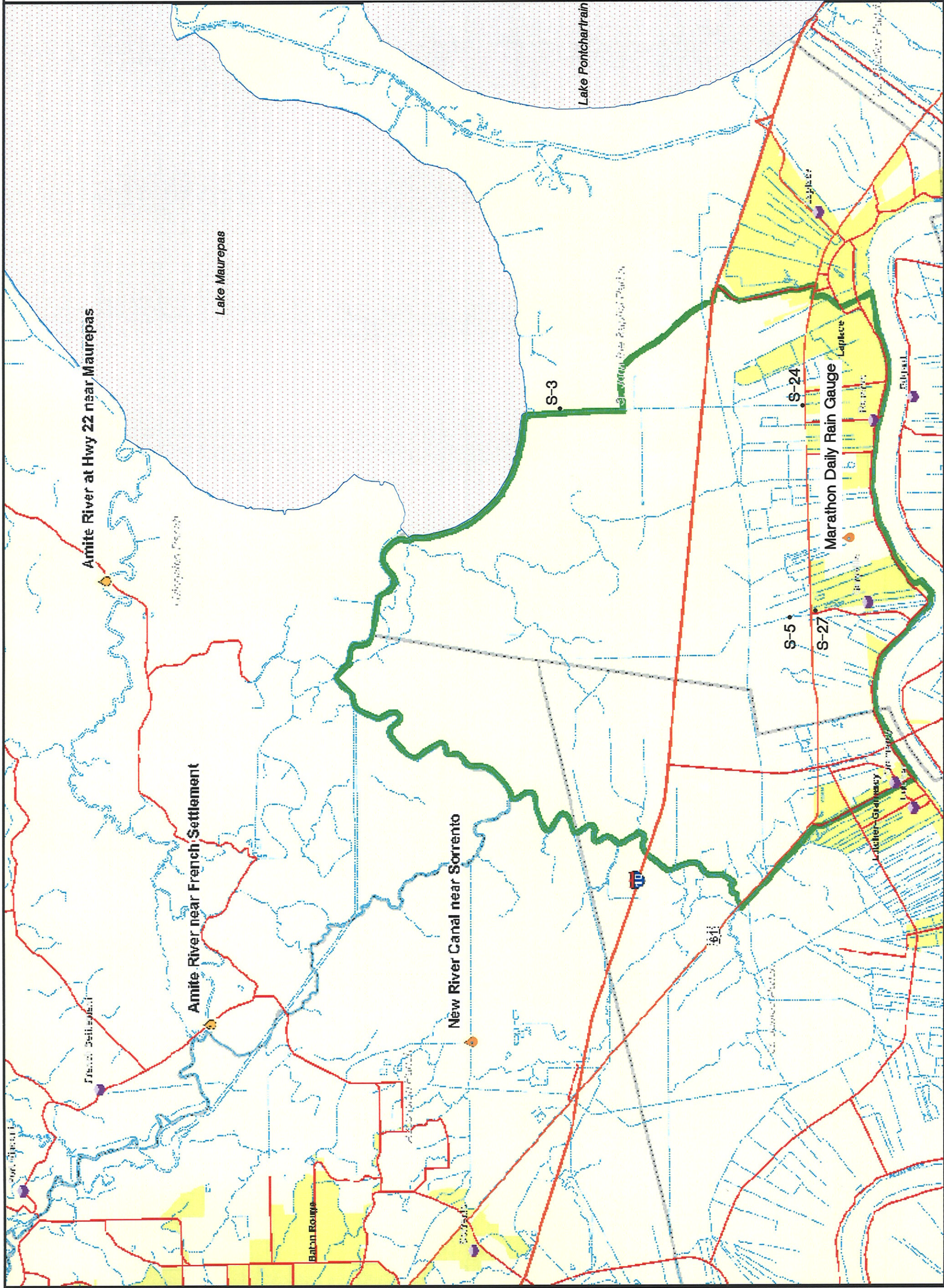
MAUREPAS DIVERSION
HYDRAULIC FEASIBILITY STUDY
RAIN GAUGE AND
STAGE GAUGE LOCATIONS
FIGURE 5

Stage Gauge
S-3

ROADS

Lake Pontchartrain

Lake Maurepas

Amite River at Hwy 22 near Maurepas

Amite River near French Settlement

New River Canal near Sorrento

S-3

S-24

Marathon Daily Rain Gauge
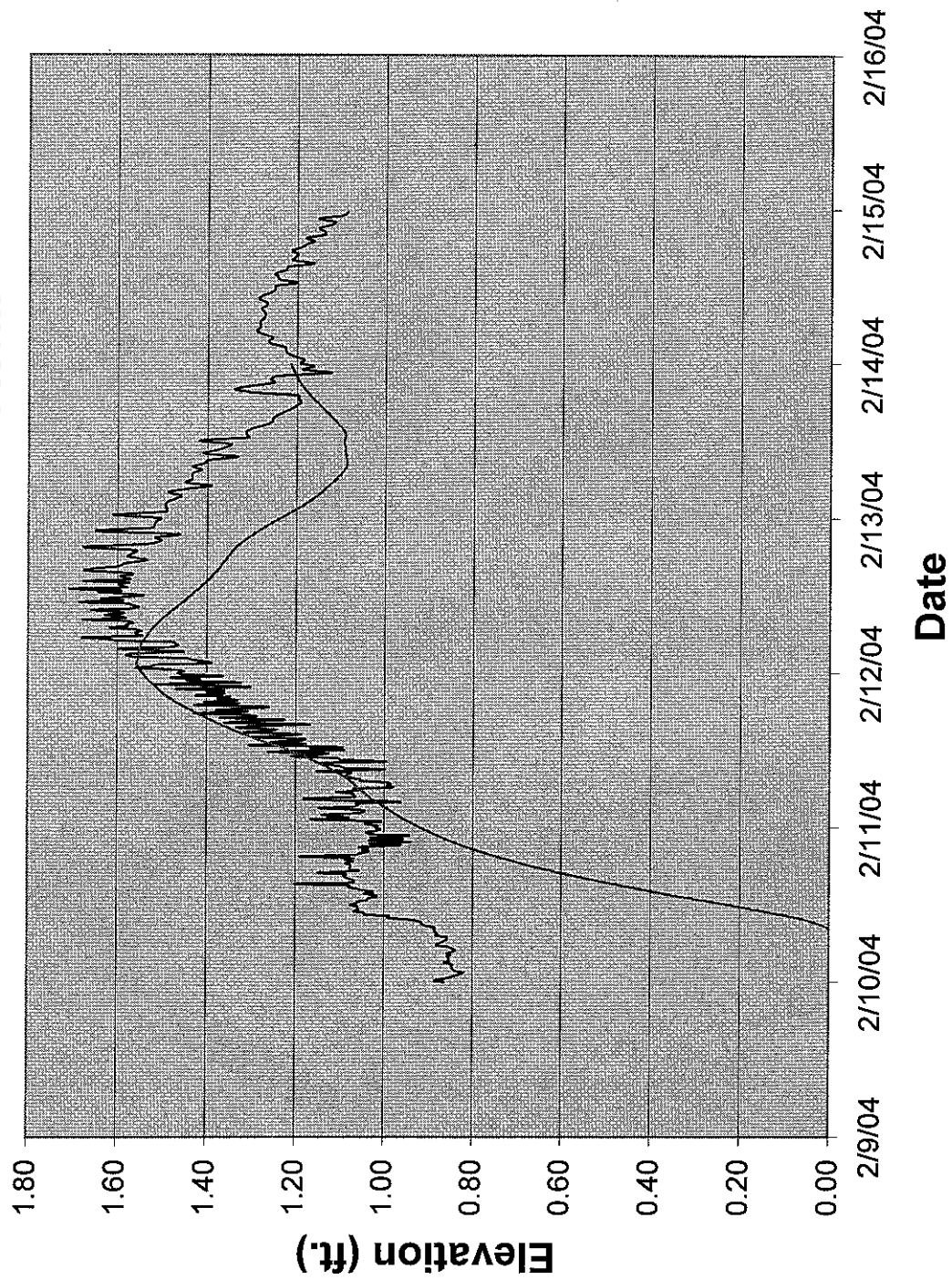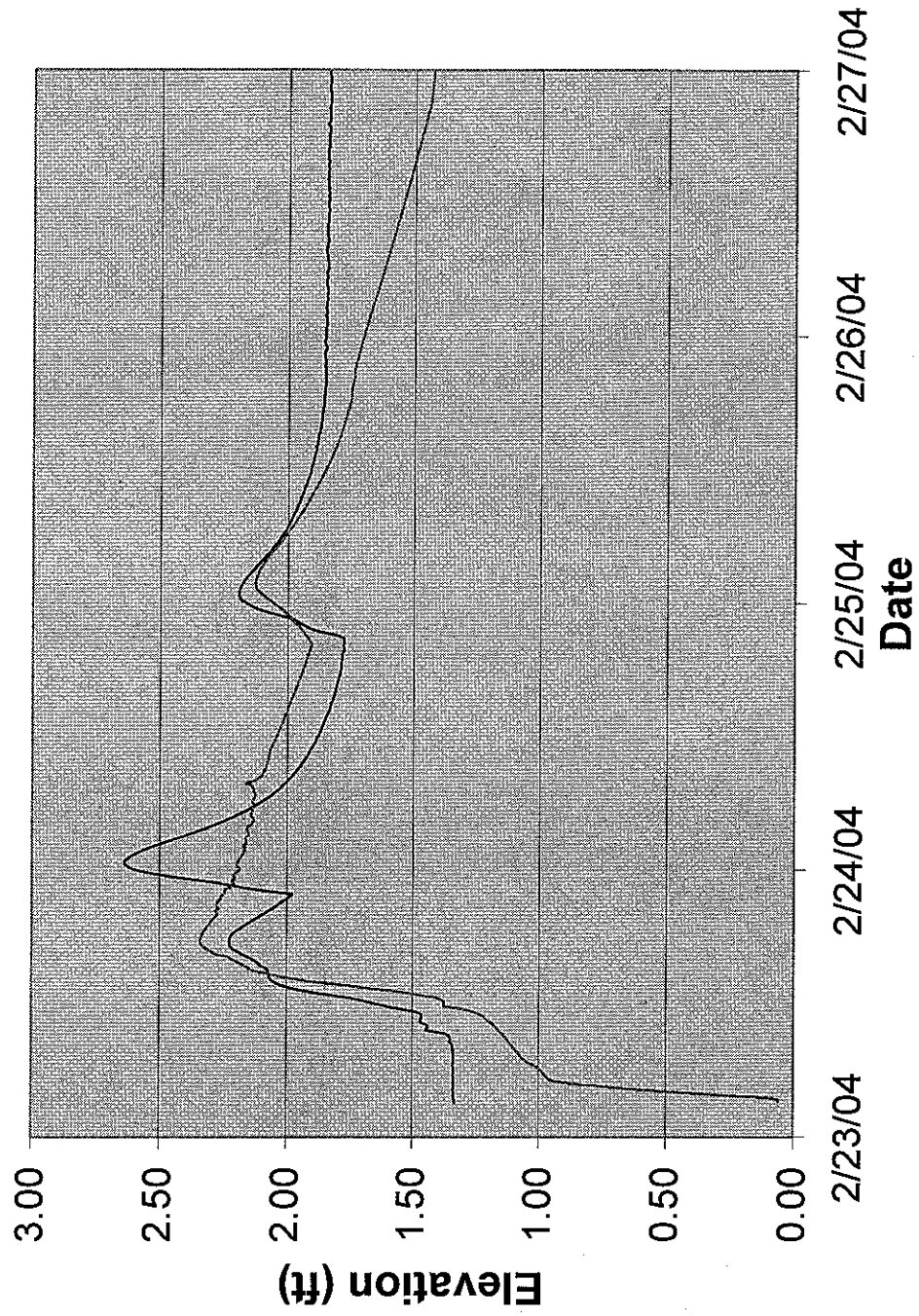
S-5

S-27

Baton Rouge
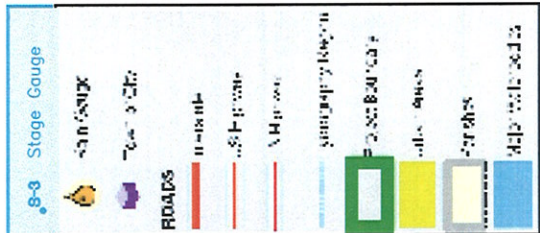
URS

Figure 6: Hope Canal
Calibration Storm
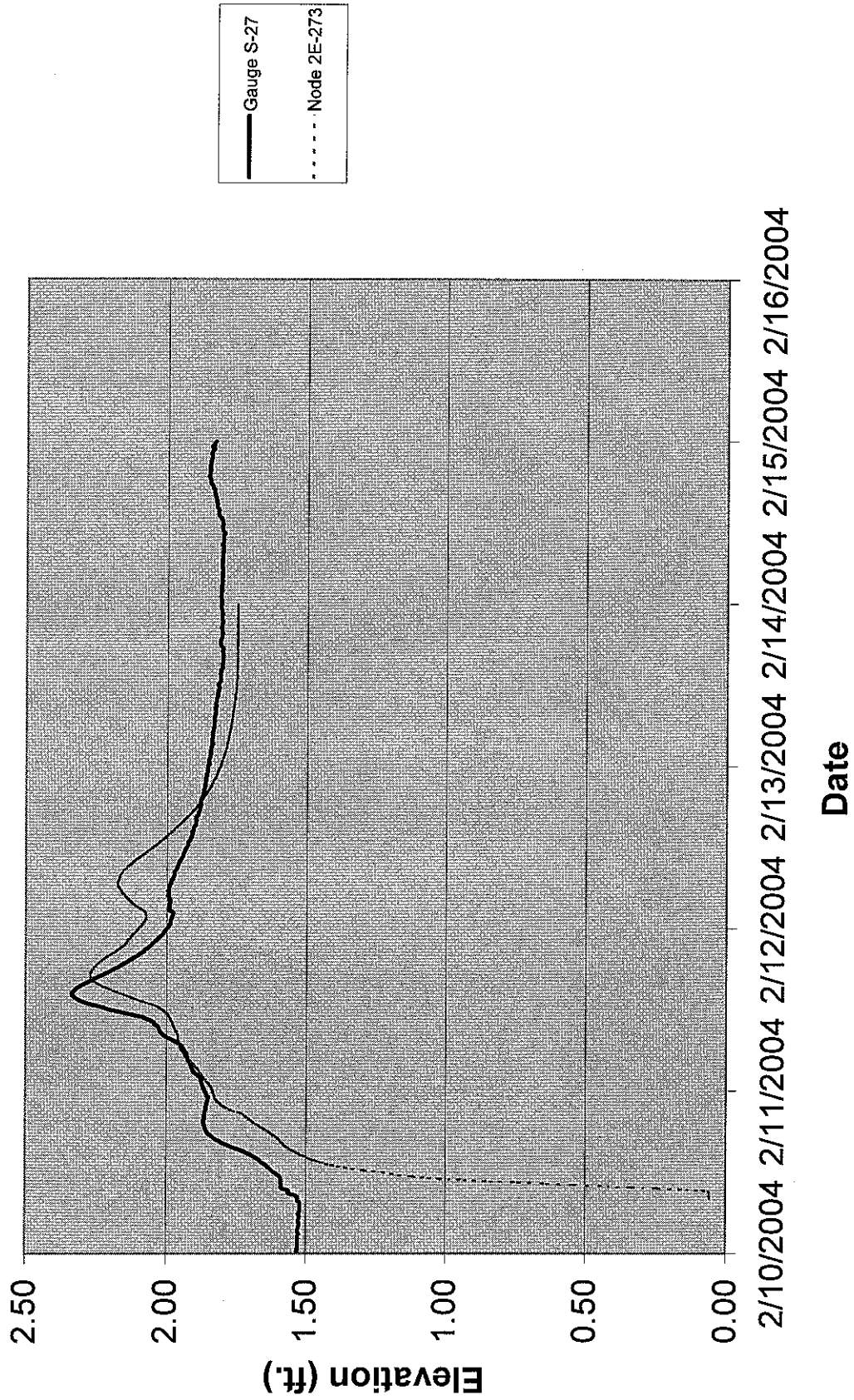
Figure 7: Reserve Relief Canal
Calibration Storm

Gauge S-24
Node 939

Figure 8: Hope Canal
Verification Storm

Figure 9: Reserve Relief Canal
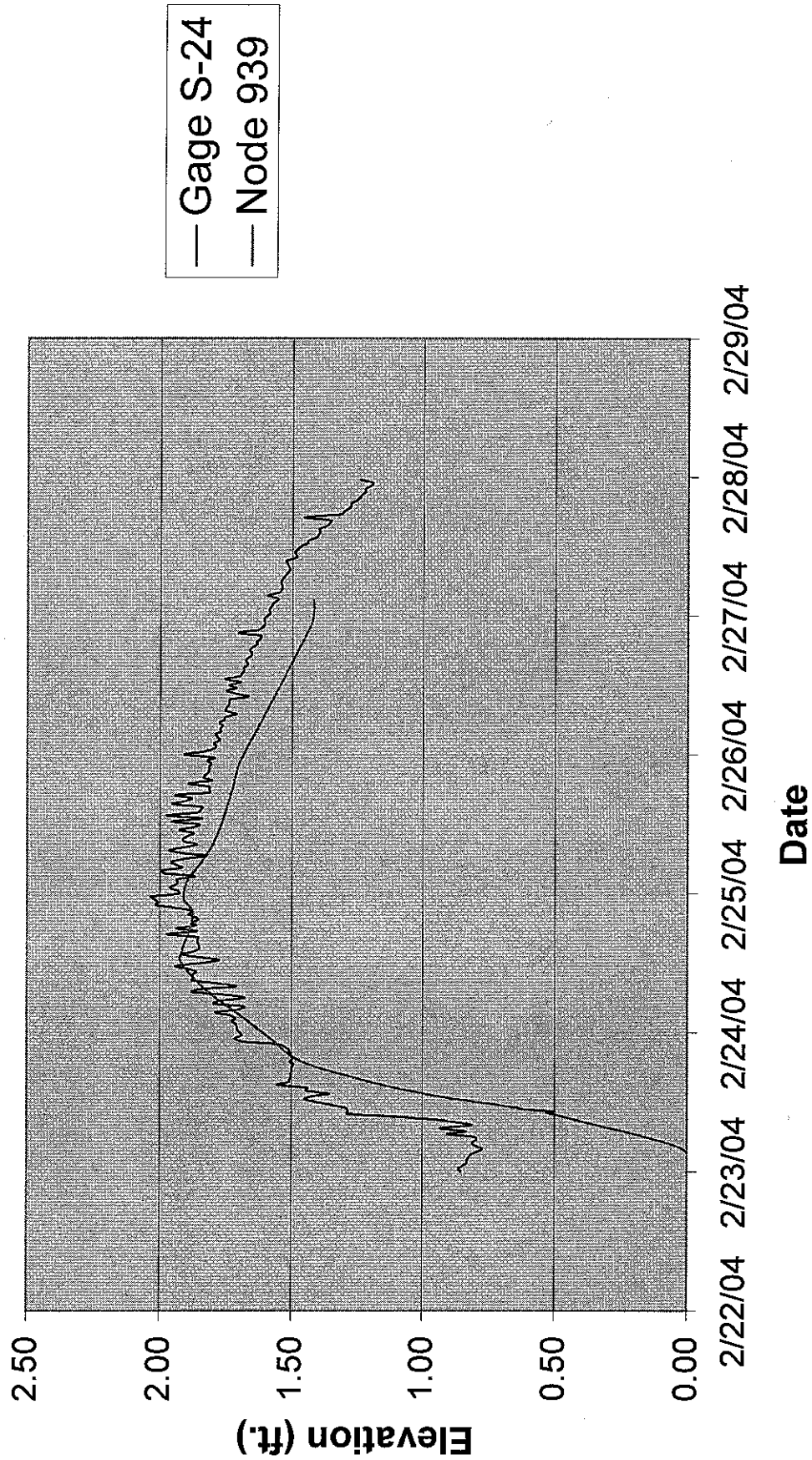Verification Storm

— Gage S-24
— Node 939

FIGURE 10: STORAGE AREA DEPTH VS TIDE NORTHERN TIER 10-YEAR STORM
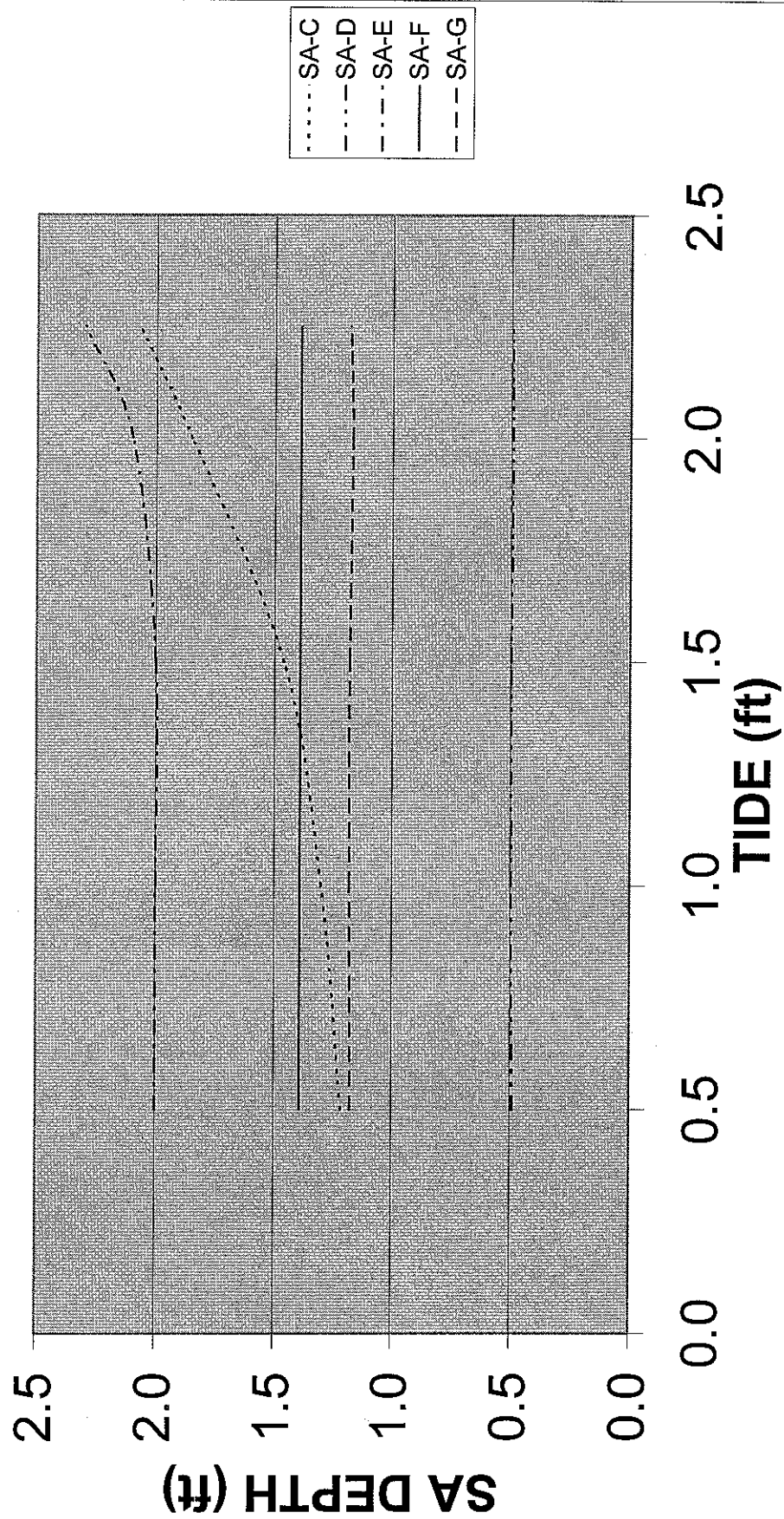
FIGURE 11: STORAGE AREA DEPTH VS TIDE
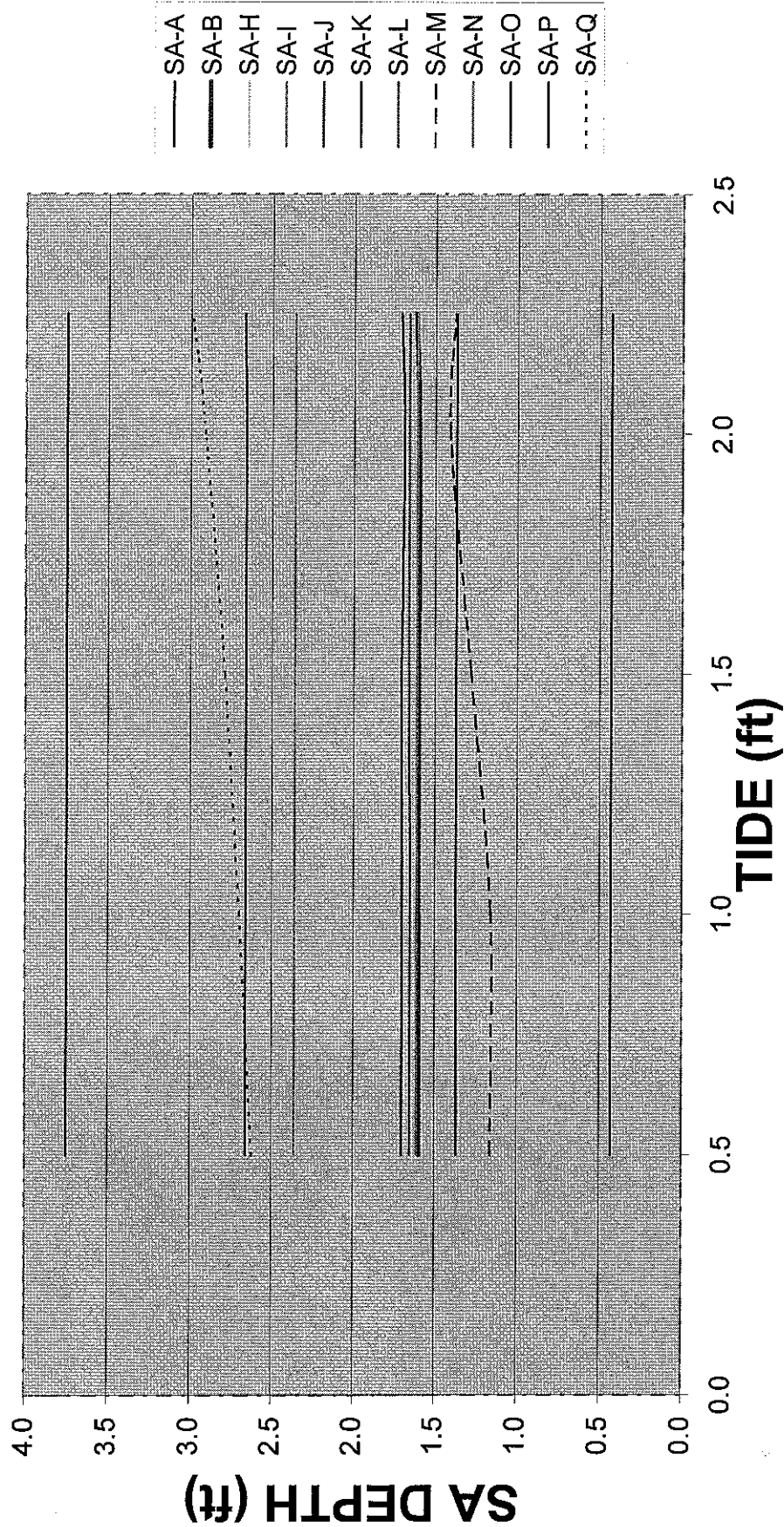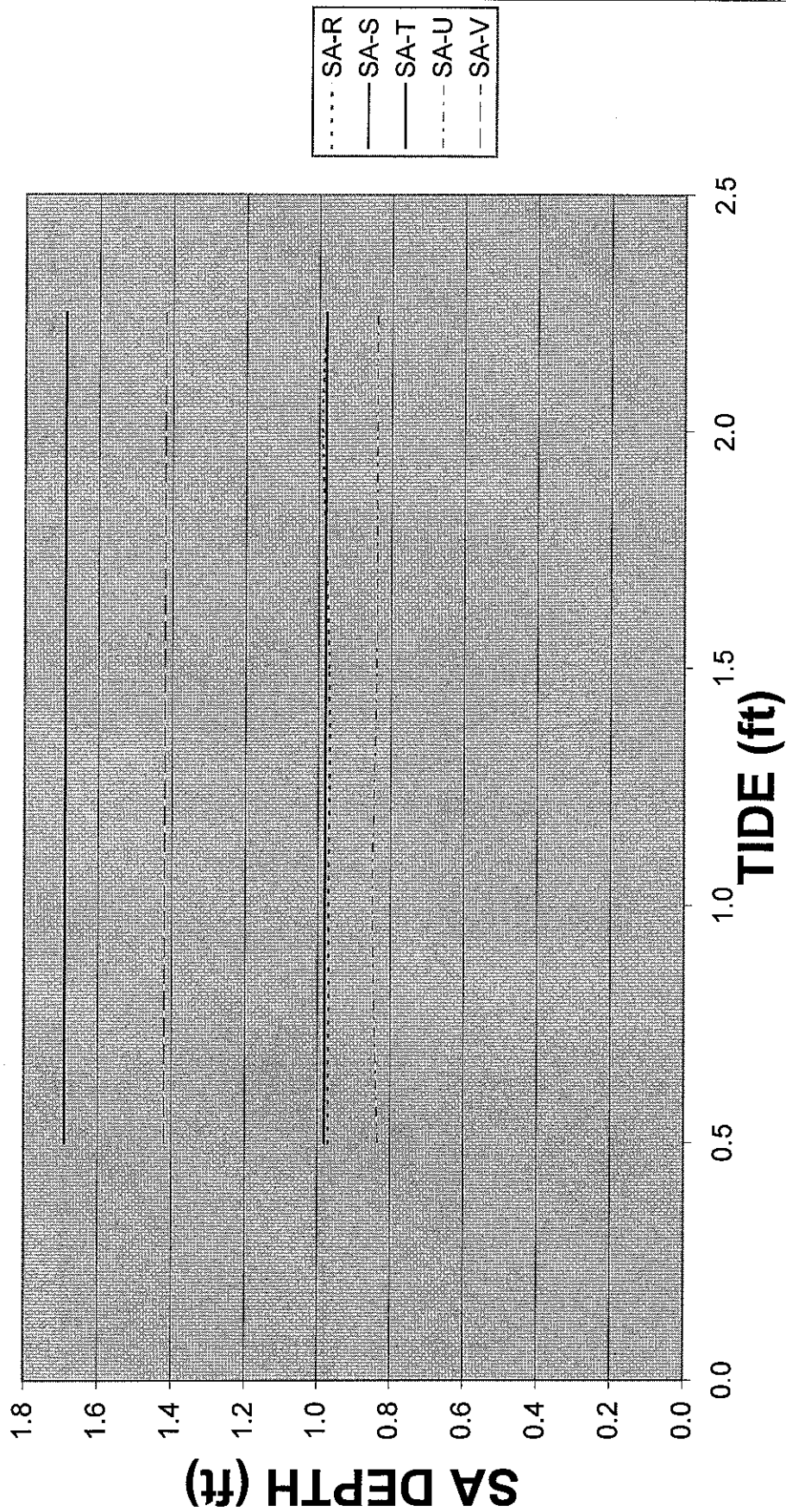MIDDLE TIER 10-YEAR STORM

FIGURE 12: STORAGE AREA DEPTH VS TIDE
SOUTHERN TIER 10-YEAR STORM

APPENDIX A

DEVELOPMENT OF HYETOGRAPHS FOR CALIBRATION STORM AND VERIFICATION STORM

Appendix A: Development of Calibration and Verification Storm Rainfall Hyetographs

There are no hourly rainfall gauges in the project area, but there are three hourly rainfall gauges nearby which can be used to develop calibration and verification storm hyetographs. They are all located to the northwest of the project area: one on the Amite River near French Settlement, one on the Amite River at Hwy 22 near the entrance to Lake Maurepas and the third, on the New River Canal near Sorrento, La. Two rainfall events, suitable for purposes of calibrating the Model, took place in the month of February, 2004; one extended from February 10 to 14 and the second from February 23 to 25. In both cases the rainfall records seemed to be fairly consistent across the area. The first event was used as the Calibration storm and the second event was used as the Verification storm. The rainfall records are presented in Tables A-1 & A-2, respectively.

The consistency of the Calibration storm is shown by the following: The total rainfall for the three rainfall gauges:

New River at Sorrento	3.03 inches	+5.9% of average
Amite at Maurepas	2.55 inches	-10.8% of average
Amite at French Settlement	2.99 inches	+4.5% of average
Average of three gauges	2.86 inches	

The consistency of the Verification storm is shown by the following:

New River at Sorrento	3.02 inches	+11.0% of average
Amite at Maurepas	2.37 inches	-12.9% of average
Amite at French Settlement	2.78 inches	-2.2% of average
Average of three gauges	2.72 inches	

Comparing the average of the total rainfalls from the three hourly gages with the gauge at Marathon (daily gauge), which is located within the study area, we have the following:

Calibration Storm:

Avg. of three gauges: 2.86 inches   Marathon: 3.00 inches   Diff. -.14 in. (-4.67%)

Verification Storm:

Avg. of three gauges: 2.72 inches   Marathon: 3.85 inches   Diff. -.29 in. (-7.62%)

Figure A-1 shows the Calibration Storm and Figure A-2 shows the Verification Storm hyetographs in graphical form.

Rainfall Hyetographs were prepared from the average rainfall of the three hourly gauges (in/hr) over time (hours) for both the Calibration Storm and the Verification Storm and run through the Model. The results are shown in Figure A-3 through A-6:

> Figure A-3: Hope Canal Calibration Storm
> Figure A-4: Reserve Relief Canal Calibration Storm
> Figure A-5: Hope Canal Verification Storm
> Figure A-6: Reserve Relief Canal Verification Storm

In the above figures, Hope Canal is represented by SWMM Node 2E-273 and Reserve Relief Canal is represented by SWMM Node 939. During the study period, a stage gauge, S-27 was placed in Hope Canal, south of Airline Drive. Node 2E-273 roughly corresponds to this location in the SWMM Model. Similarly, Stage Gauge S-24 was placed in Reserve Relief Canal north of Airline Drive. SWMM Node 939 roughly corresponds to this location in the Model. Figures A-3 through A-6 are plotted along with the appropriate stage gauge record for the Calibration and Verification periods.

Modified Rainfall Hyetographs: Rainfall Hyetographs were then prepared in which the hourly amounts were modified so that the Daily totals matched the Marathon Daily Gauge. This was done by computing a daily Marathon Factor as the ratio of the Marathon Gauge reading to the daily total of the computed hourly average of the three gauges for each day and multiplying the hourly averages by this factor. This was done for both the Calibration Strom and the Verification Storm. The Modified Calibration and Verification Storms were run through the Model. The results are shown in Figures A-7 through A-10.

Evaluation of Modified Rainfall hyetographs: The following observations can be made regarding the hydrographs shown in Figures A-1 through A-10:

1. The Model is imperfect. None of the hydrographs mimic the gauge record exactly.
2. Some maximum (and minimum) water surface elevations computed by SWMM are greater than the gauge reading for the same time period and some are less.
3. Some peaks in the Model led the gauge record, in time, and some other Model peaks lagged the gauge record.
4. The above statements are true for both the Calibration Storm and the Verification Storm and for the Unmodified Rainfall and the Modified Rainfall. There was no consistency in the variation between the Model Hydrograph and the Gauge Record.
5. The hydrographs at Reserve Relief Canal showed very little variation between the modified rainfall and unmodified rainfall. Therefore, they were excluded from consideration in evaluating the use of the Marathon Gauge. Only the hydrograph at Hope Canal (Node 2E-273) and Gauge S-27 were compared in this analysis.
6. Qualitative evaluation of the resulting hydrographs for the two storms and for the Unmodified and Modified Rainfall, comparing them to the Gauge Record, produces mixed results. The Unmodified Rainfall produced hydrographs at Hope Canal (Node 2E-273) which had some positive aspects and some negative aspects as compared with the Gauge S-27 record. The same is true for the Modified Rainfall case: some aspects of the

hydrographs are positive and some are negative[1]. Therefore, a <u>quantitative</u> method of evaluation was sought. Four or 5 points (either peaks or valleys) were chosen for each storm output hydrograph to compare with the corresponding gauge hydrograph. These points are shown in Figures A-11 through A-14 and tabulated in Tables A-3 and A-4.

7. Referring to Table A-3, the average difference in elevation of the four points in the Calibration Storm was 0.044 feet and .059 feet for the five points in the Verification Storm. The Model lagged the gauge in the Calibration Storm by an average of 2.53 hours and 0.27 hours in the Verification Storm.

8. Table A-4 shows the same data for the Modified Rainfall simulation. The average difference in water surface elevation between the Model and the gauge for the four points in the hydrograph is .078 feet for the Calibration Storm and 0.210 feet for the five points in the Verification Storm. The Model hydrograph lagged the gauge by and average of 2.63 hours in the Calibration Storm and 1.86 hours in the Verification Storm.

9. Results for the Calibration Storm and the Verification Storm were combined as shown in Tables A-3 & A-4. The average difference in water surface elevation at the seven points of observation, for the Unmodified Rainfall simulation is 0.05 feet and the average lag is 1.4 hours. The average difference in water surface elevation at the same points, for the Modified Rainfall simulation is 0.144 feet and the average lag is 2.25 hours.

10. There were a few features (peaks or troughs) which were present in either the Model or the Gauge which were not present in the corresponding curve. The Unmodified Rainfall curves had a total of two such points, but the Modified Rainfall curves had four points.

11. From this analysis of the data, it would seem that the Unmodified Rainfall produced resulting hydrographs which more nearly matched the corresponding Gauge record, than did the Modified Rainfall hydrographs.

12. The area under the curves for the unmodified rainfall and the modified rainfall Model was compared to the area under the curve for the gauge record (Calibration Storm). If there were a significant difference in the area under the Model curves when compared to the Gauge curve, this difference might lend credence to one rainfall scheme over the other. The comparison was begun from a point at which the two model hydrographs were very nearly the same (1.50 ft., Unmodified and 1.51 ft., Modified; both at 14:13 hours on 2/10/2004) and ended at 23:47 hours on 2/13/2004, when both Model hydrographs were identical (1.75 ft.). The corresponding values for the Gauge Record was: 1.69 ft. at 14:20 hours on 2/10/2004 and 1.91 ft. at 23:50 hours on 2/13/2004. The total area under the curve, in foot-hours, were found to be as follows: Gauge 164.20, Unmodified 162.95 (0.76% difference) and Modified 163.90 (0.68% difference). The percent differences are too similar and too small to be of any consequence. Therefore, the area under the curve method of evaluating the difference is inconclusive.

Conclusion: Although both methods of computing rainfall have their advantages and disadvantages, it appears that the output at Hope Canal (Node 2E-273) more closely fits the

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[1] For instance, in the Calibration Storm, the Hope Canal Node 2E-273 hydrograph (Figure A-3) showed the same general pattern of peaks and troughs that Gage S-27 showed, except that the primary peak on Feb. 11 was smaller in the Model than the Gauge, but the secondary peak on Feb. 12 was greater in the Model than in the Gauge; however, the Modified Rainfall hydrograph (Figure A-7) was closer to the Gauge reading in the primary peak, but had no secondary peak at all, and the curve, for 6 hours before the primary peak, was significantly higher in than in the Gauge curve.
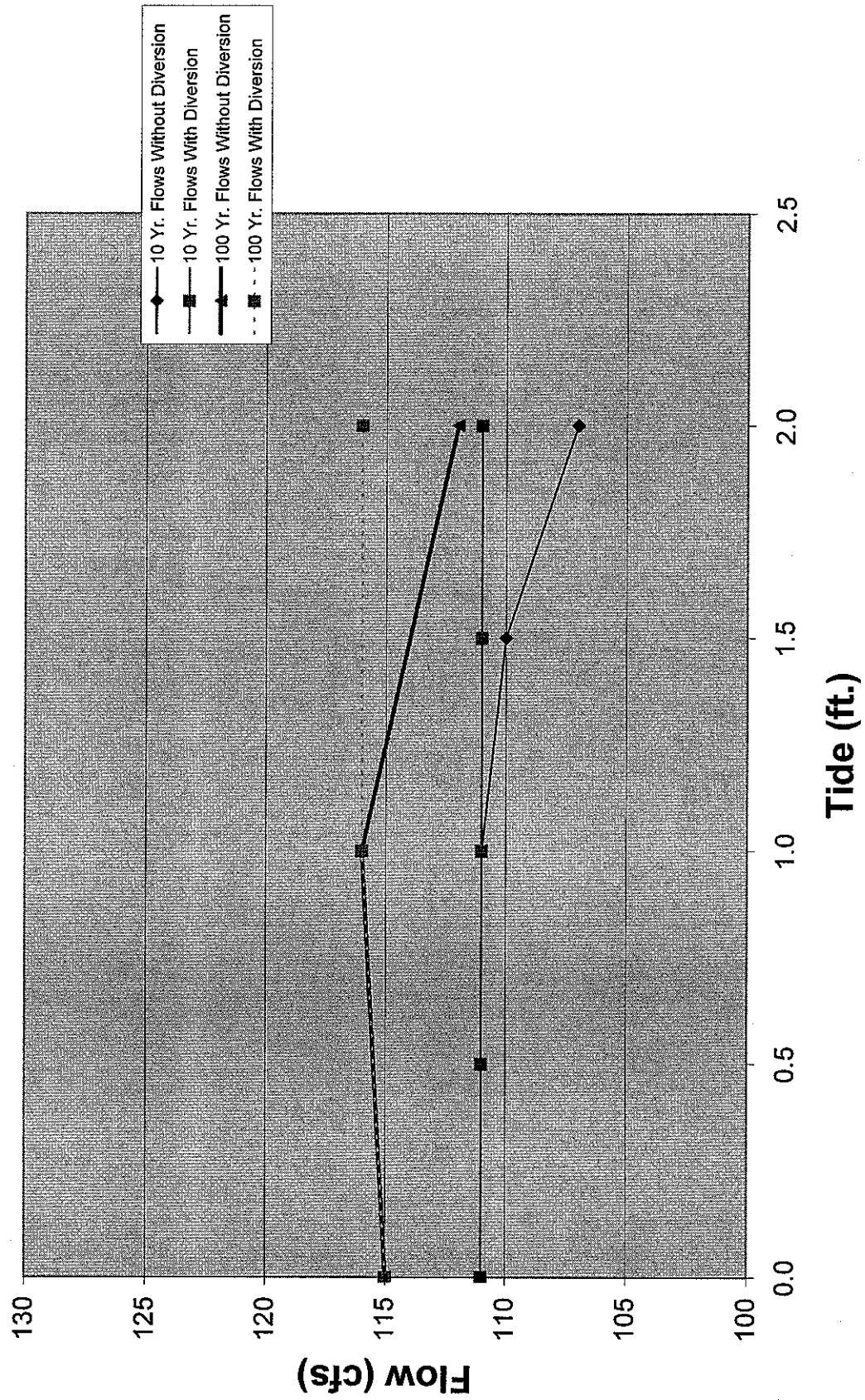
gauge record (Gauge S-27) for the case in which the Marathon Gauge is disregarded, than the case in which the rainfall is modified to better match the daily rainfall at Marathon. Therefore, the Marathon gauge was disregarded in calibrating the Model. It is of note, that in either the modified case or the unmodified case the difference between the Node 2E-273 hydrograph and the Gauge S-27 hydrograph was not systematic. That is, some peaks were greater and some were less. The Model seemed to lag the gauge on a fairly consistent basis, but the average difference was on the order of one hour. The rainfall hyetograph was input in time increments of one hour. This level of precision of the timing of the input limits the precision of the timing of the output.

Calibration of the Model: Comparing seven points in the Hope Canal Node 2E-273 hydrograph with similar points in the Gauge S-27 record yielded a total average difference, for two storms (calibration and verification), of 0.05 feet. The Model was, therefore, considered calibrated without any further revisions. No attempt was made to modify rainfall hyetographs to confirm to the Marathon Gauge. The hyetographs used in the Calibration Storm and the Verification Storm are shown in Tables A-1 & A-2, respectively and displayed in Figure A-1 & A-2, respectively.
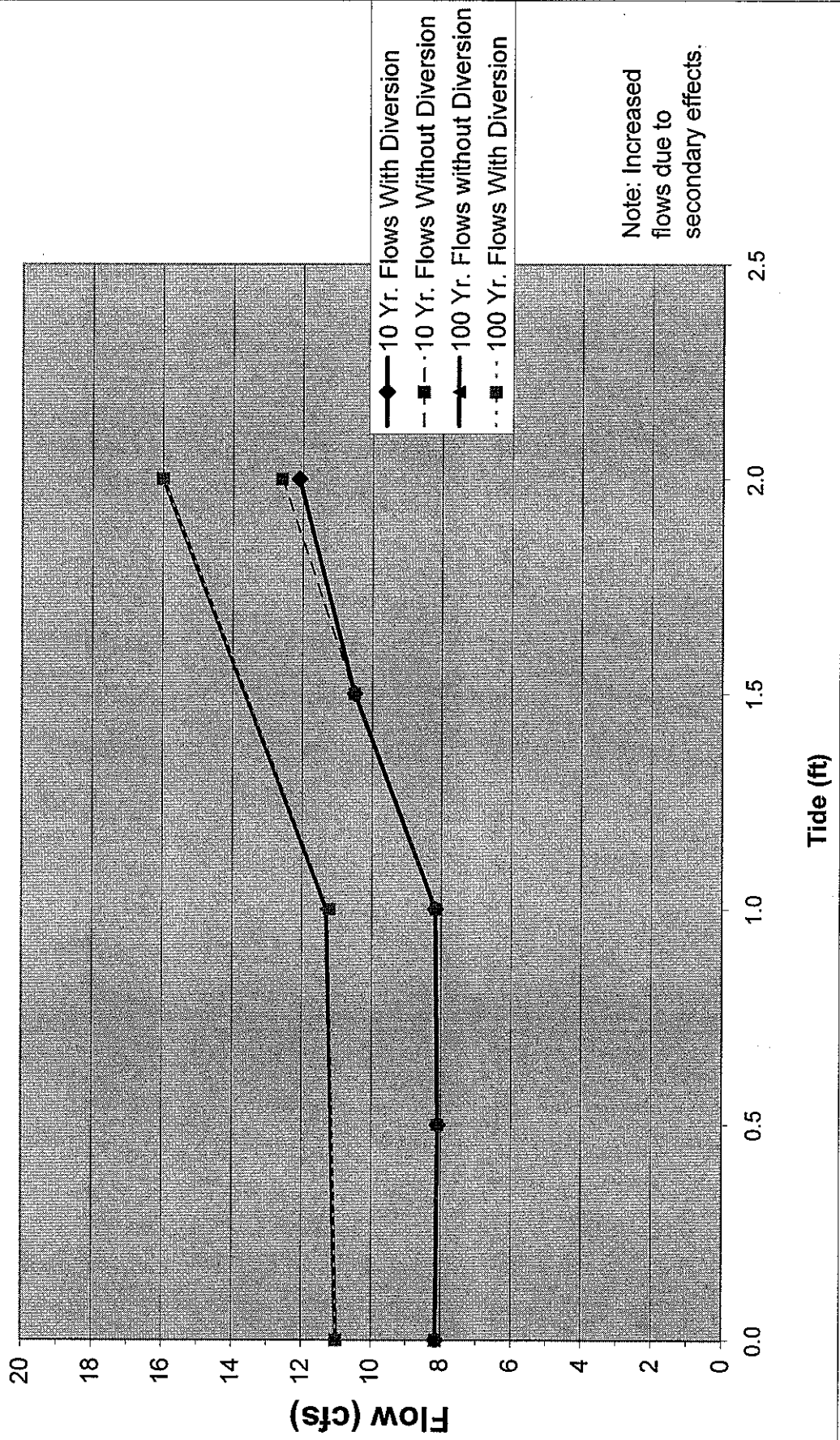
APPENDIX B

PERFORMANCE CURVES
FLOW VS TIDE FOR 1-D MODEL OUTFLOW POINTS
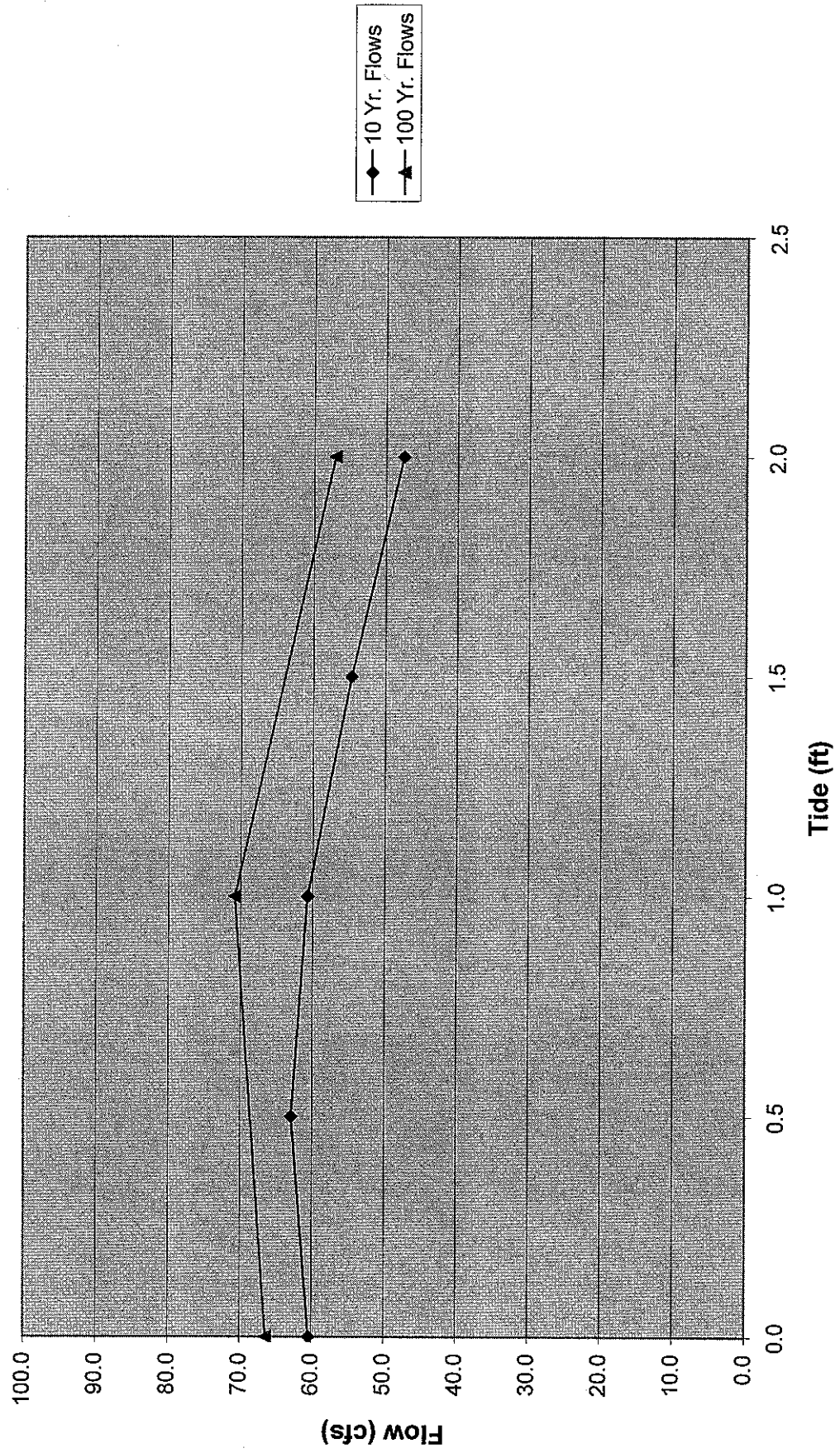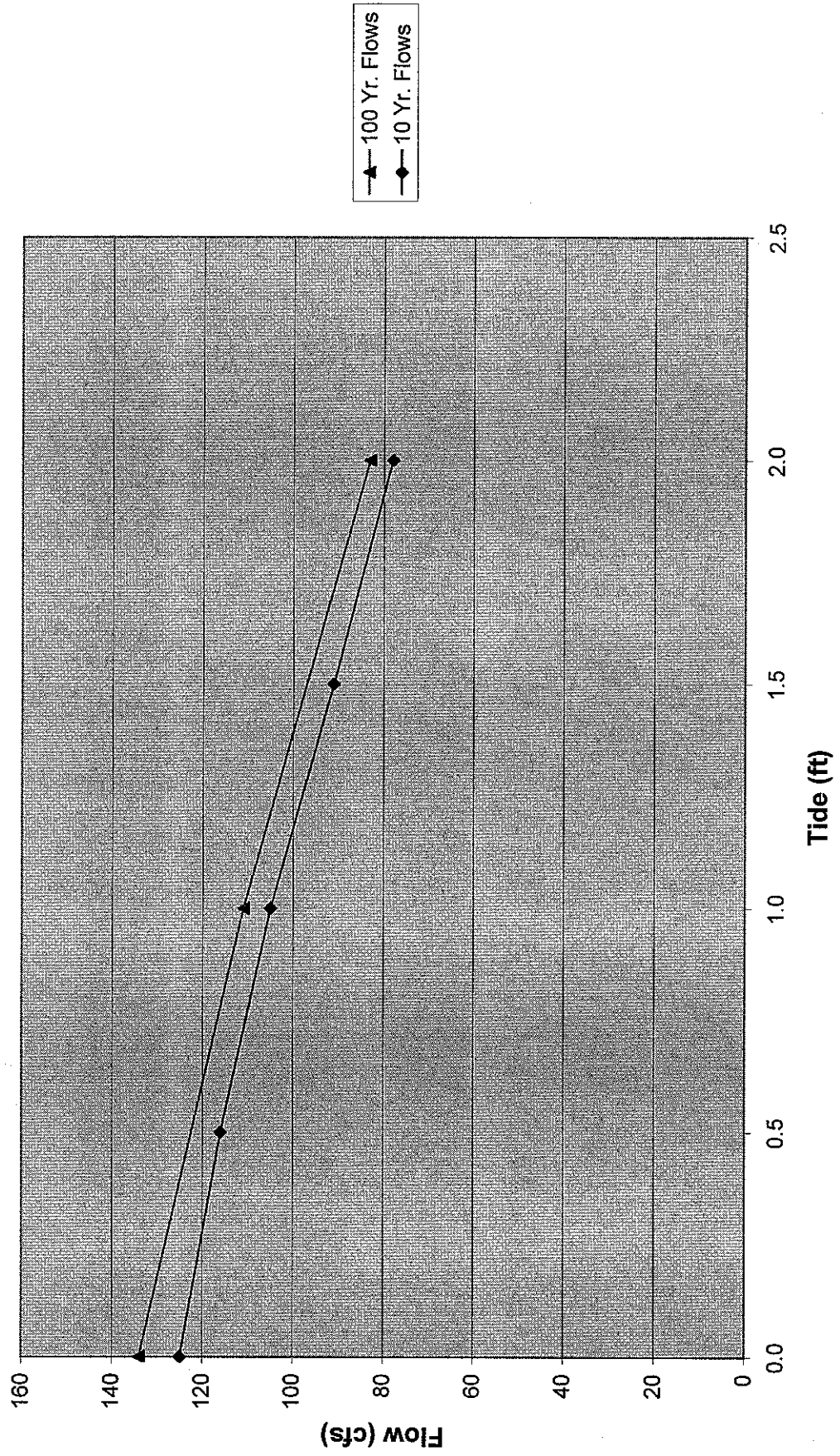## 10-YEAR & 100-YEAR RAINFALL EVENTS

Peak Flows to Marsh 1-3

Legend:
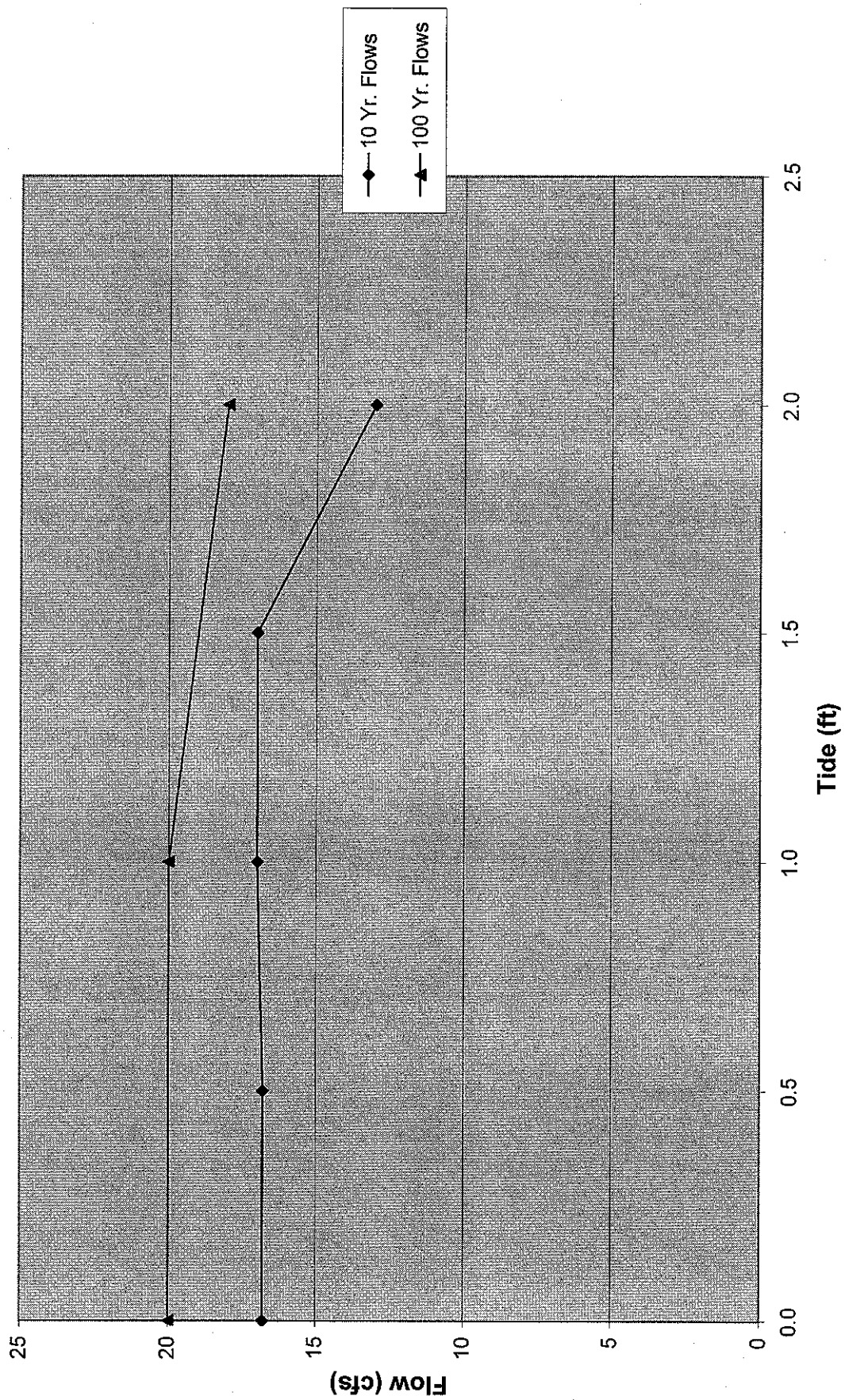- 10 Yr. Flows Without Diversion
- 10 Yr. Flows With Diversion
- 100 Yr. Flows Without Diversion
- 100 Yr. Flows With Diversion

X-axis: Tide (ft.)

Y-axis: Flow (cfs)

Peak Flows to Marsh 4
Bougere Canal

Legend:
- 10 Yr. Flows With Diversion
- 10 Yr. Flows Without Diversion
- 100 Yr. Flows without Diversion
- 100 Yr. Flows With Diversion

Note: Increased flows due to secondary effects.

Flow (cfs)

Tide (ft)

Peak Flows to Marsh 5
San Francisco Plantation Canal

Legend:
- 10 Yr. Flows
- 100 Yr. Flows

X-axis: Tide (ft) — 0.0, 0.5, 1.0, 1.5, 2.0, 2.5

Y-axis: Flow (cfs) — 0.0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0, 100.0

Peak Flows to Marsh 6
Dolson Canal

Peak Flows to Marsh 7

Legend: 10 Yr. Flows, 100 Yr. Flows

X-axis: Tide (ft)
Y-axis: Flow (cfs)

Peak Flows to Marsh 8

Flow (cfs)

Tide (ft)
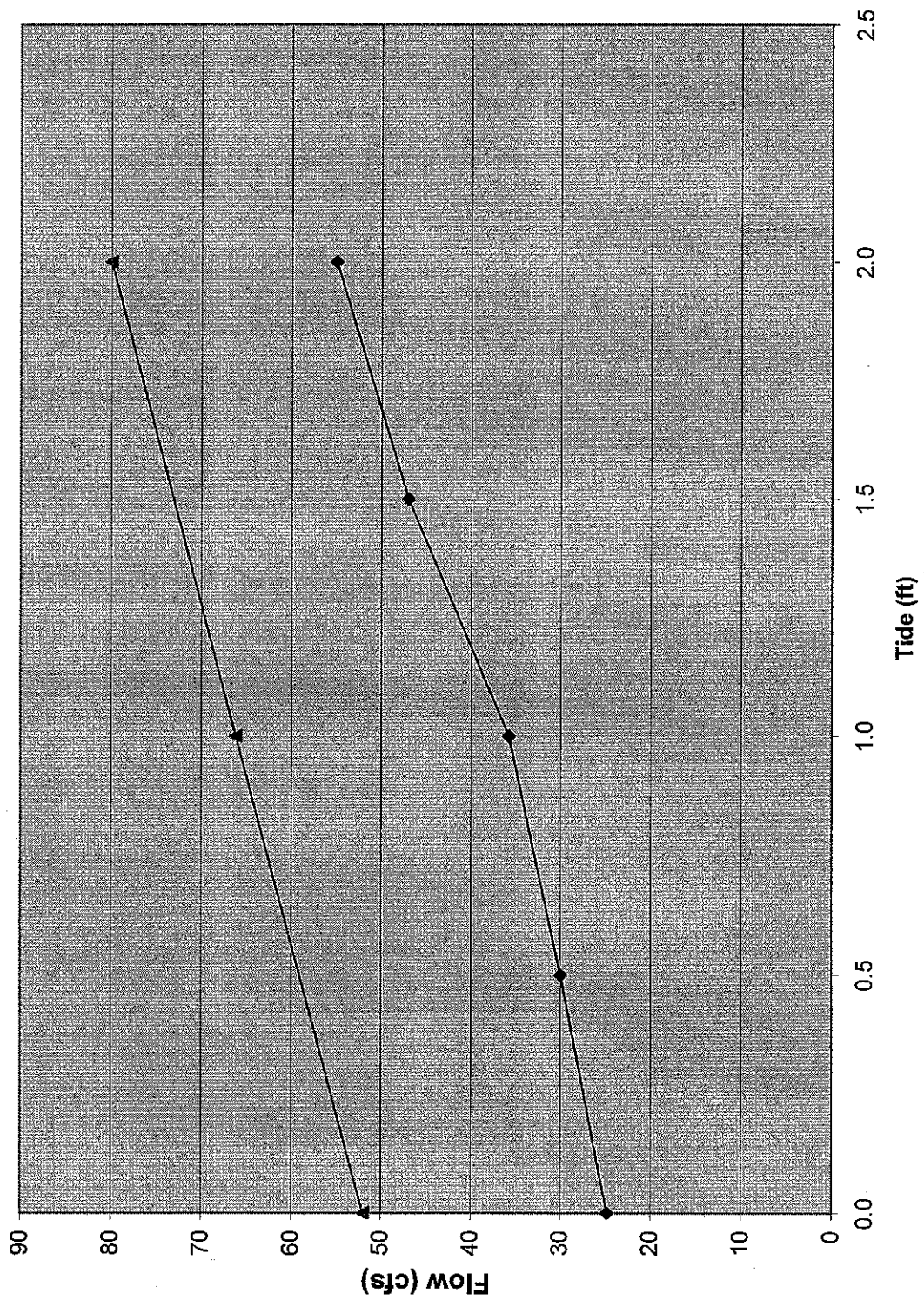
10 Yr. Flows
100 Yr. Flows

Note: Flows increasing due to secondary effects from other canals

Peak Flows to Marsh 9
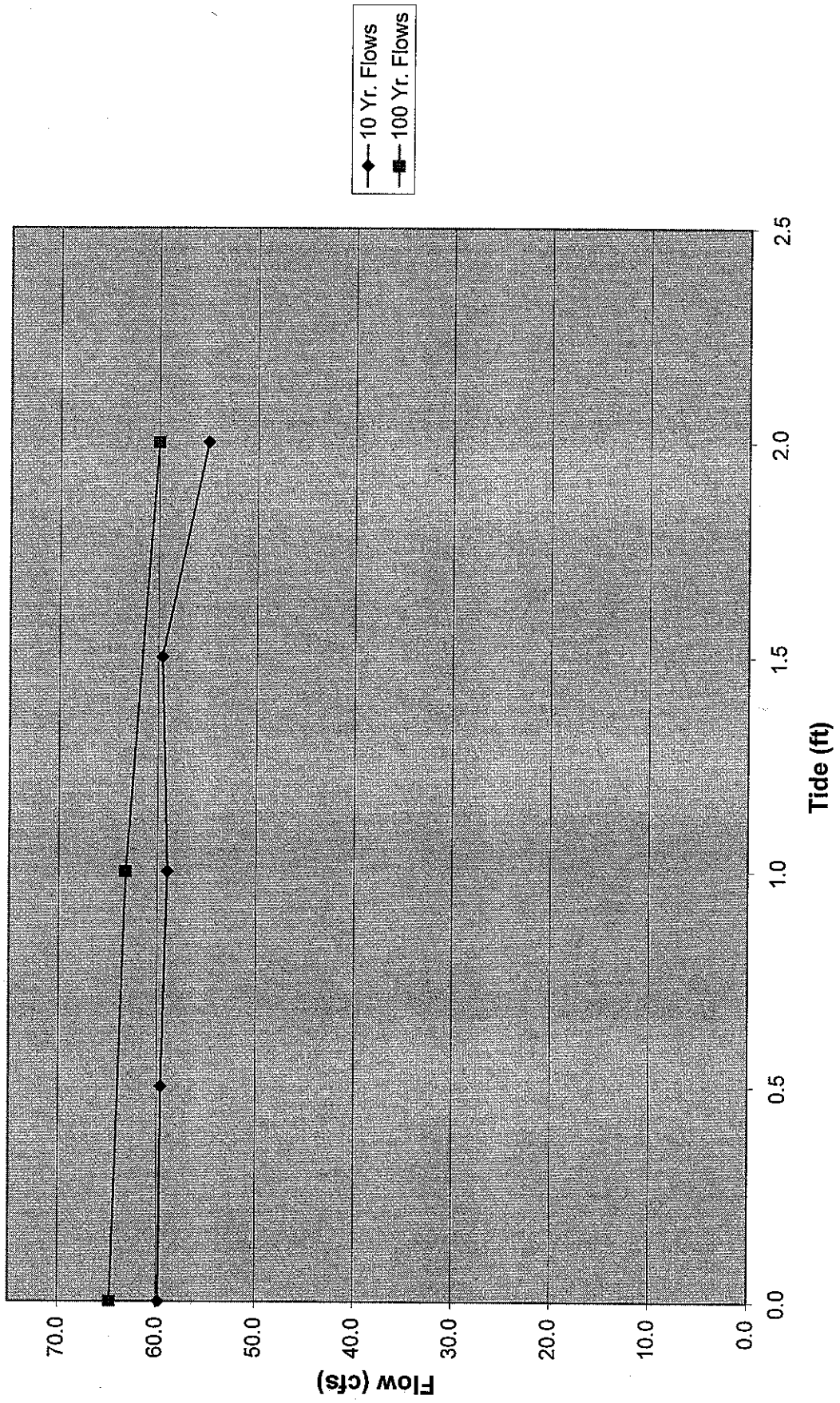
Peak Flows to Marsh 10
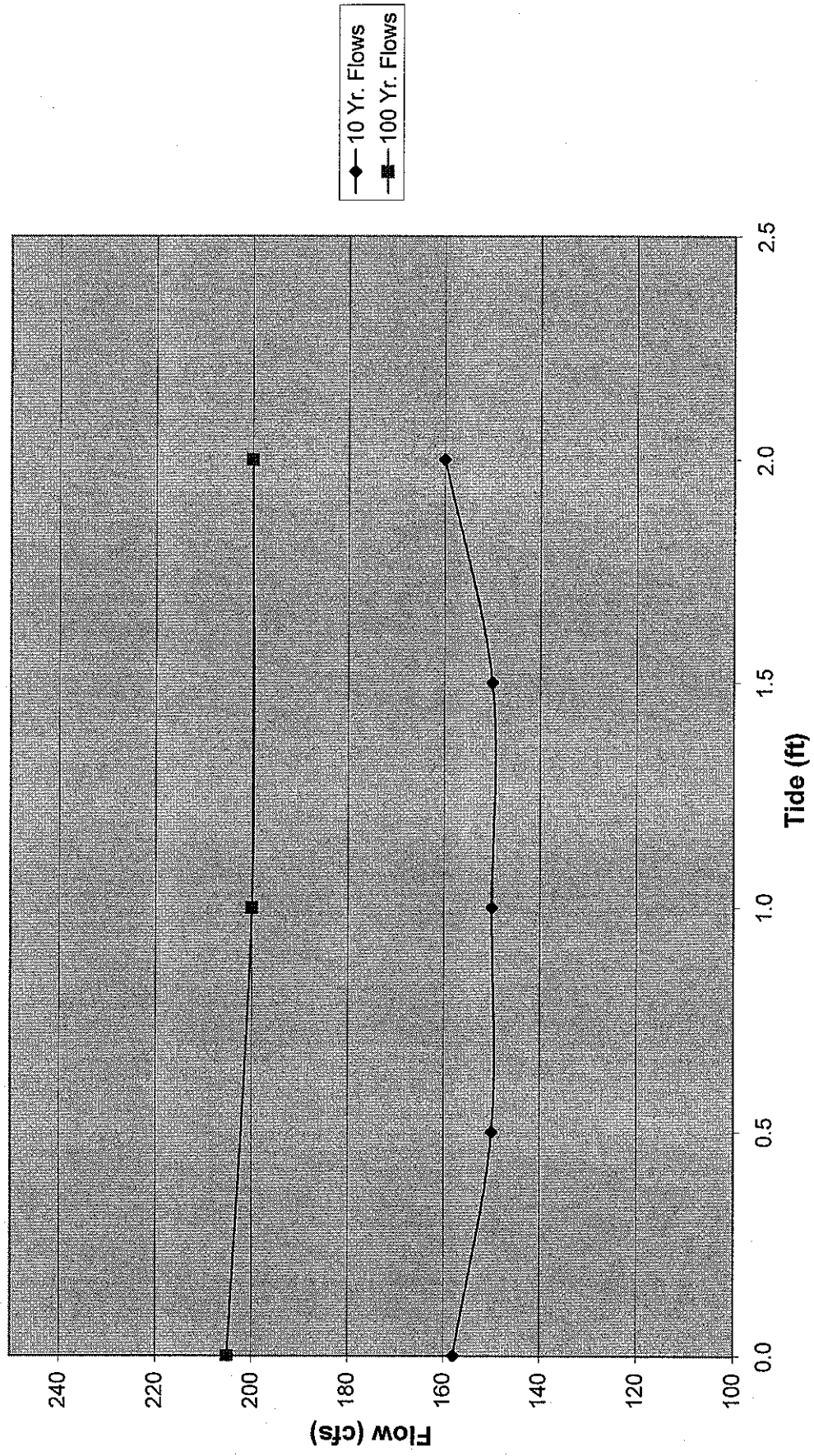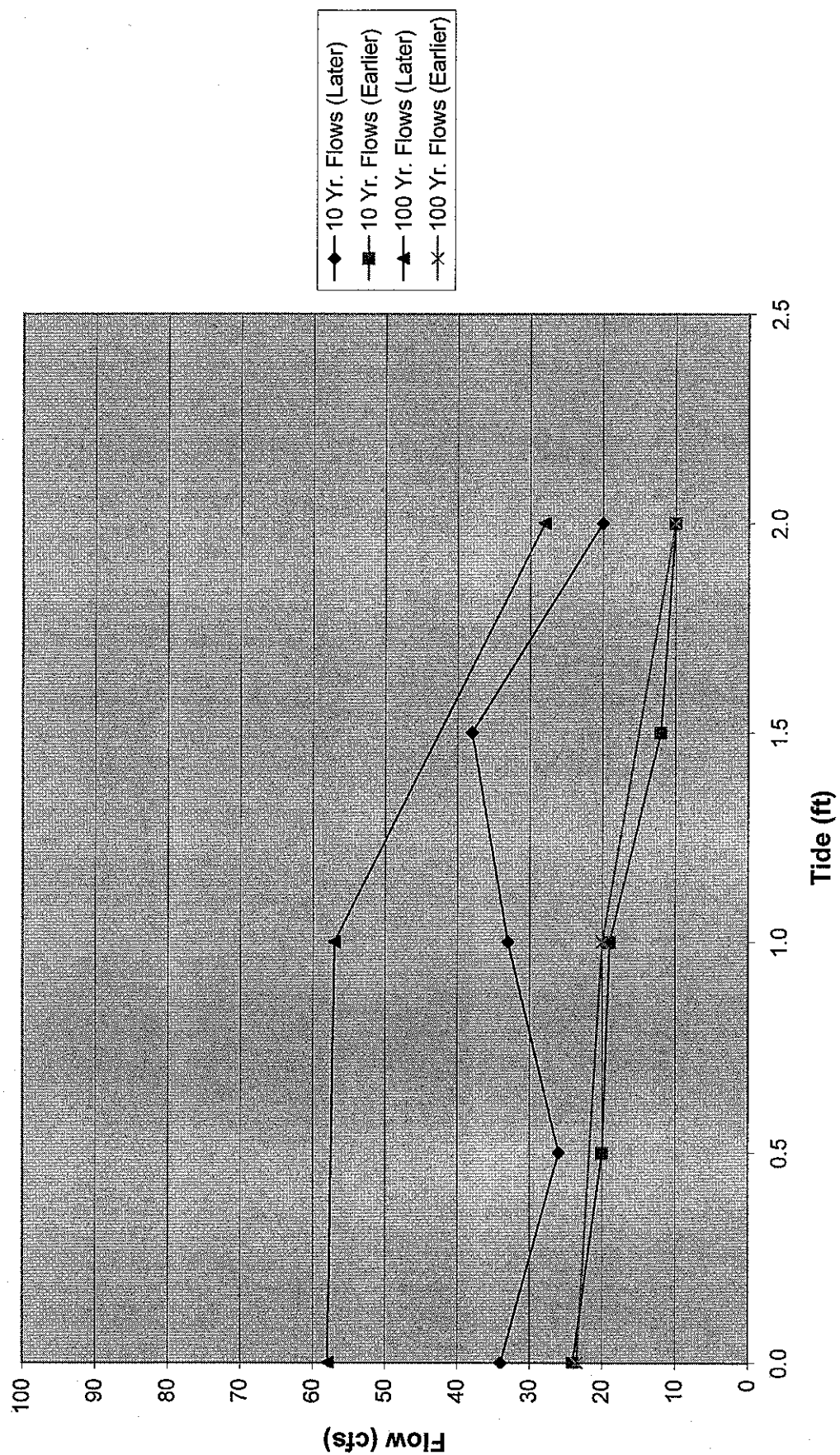**Lions Canal**

Legend:
- 10 Yr. Flows
- 100 Yr. Flows

Tide (ft)

Flow (cfs)
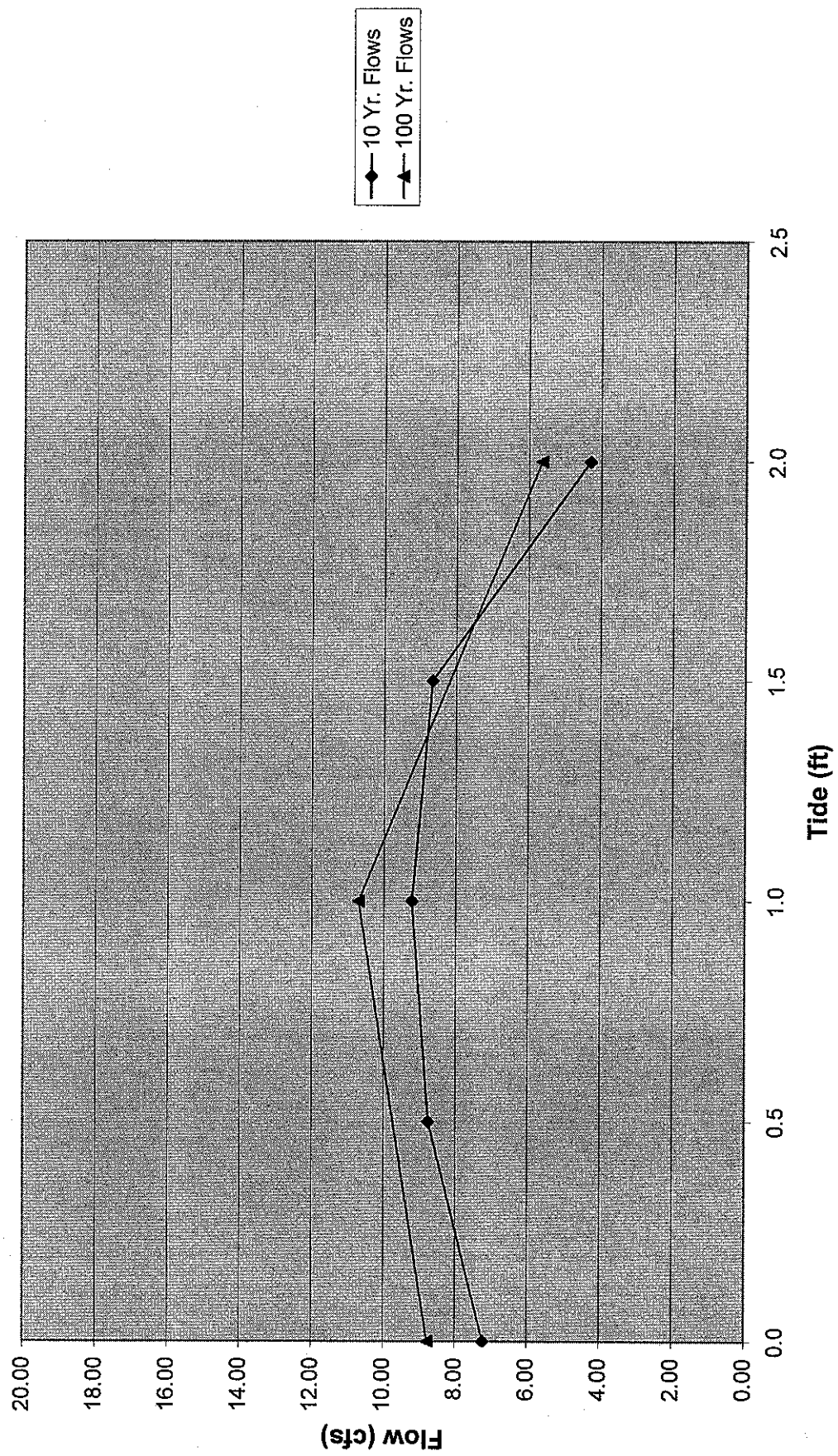
Peak Flows to Marsh 11
Guidry Canal
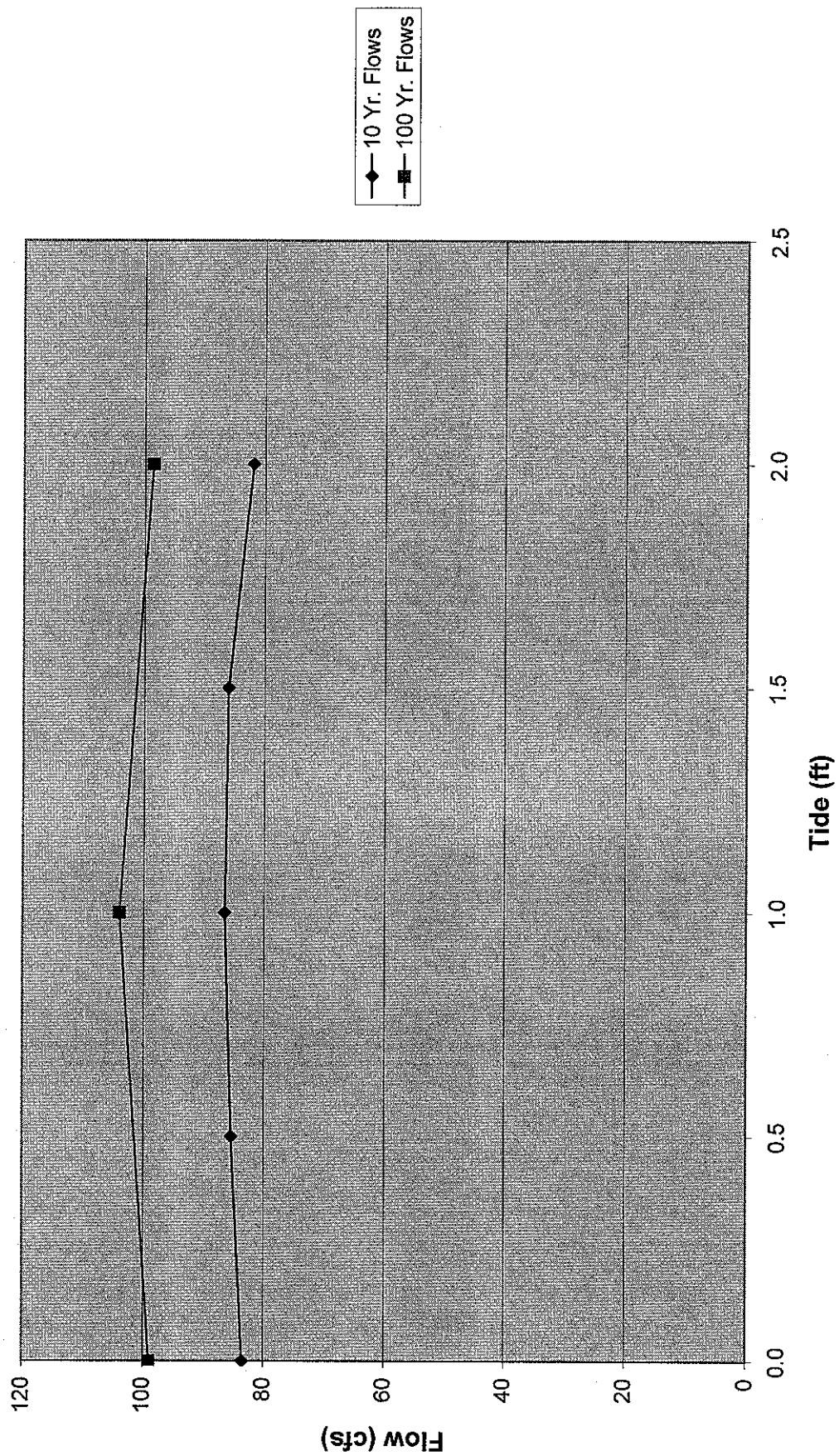
Peak Flows to Marsh 12
Godchaux Canal

Peak Flows to Marsh 13
Lumber Yard Canal

Legend:
- 10 Yr. Flows (Later)
- 10 Yr. Flows (Earlier)
- 100 Yr. Flows (Later)
- 100 Yr. Flows (Earlier)

X-axis: Tide (ft)

Y-axis: Flow (cfs)

Peak Flows to Marsh 14
Hotard Canal

Legend: 10 Yr. Flows (♦), 100 Yr. Flows (■)

Y-axis: Flow (cfs) — 0.0 to 100.0

X-axis: Tide (ft) — 0.0 to 2.5
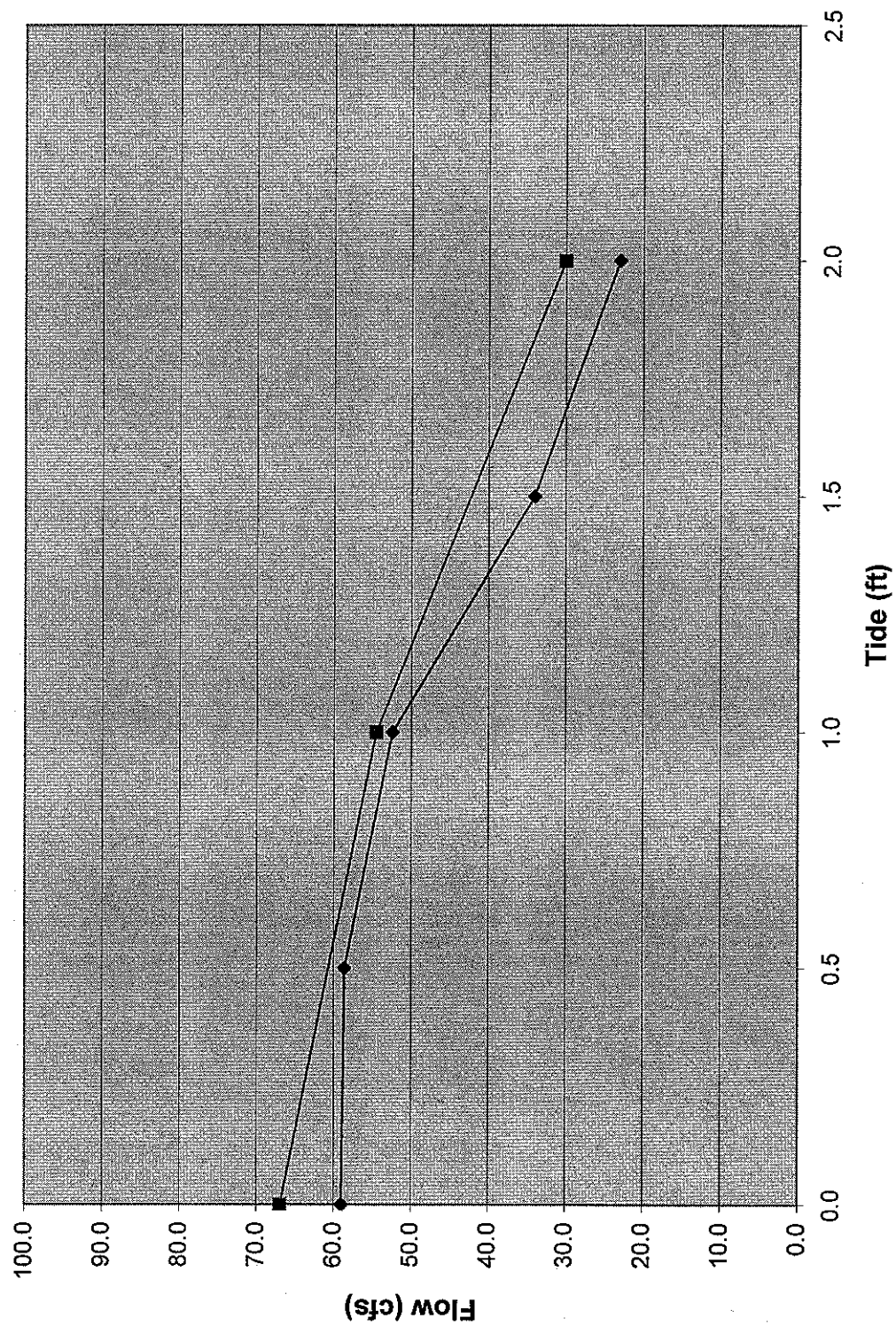
Peak Flows to Marsh 15
Airline Drive

Flow (cfs) vs Tide (ft)

Legend:
10 Yr. Flows
100 Yr. Flows
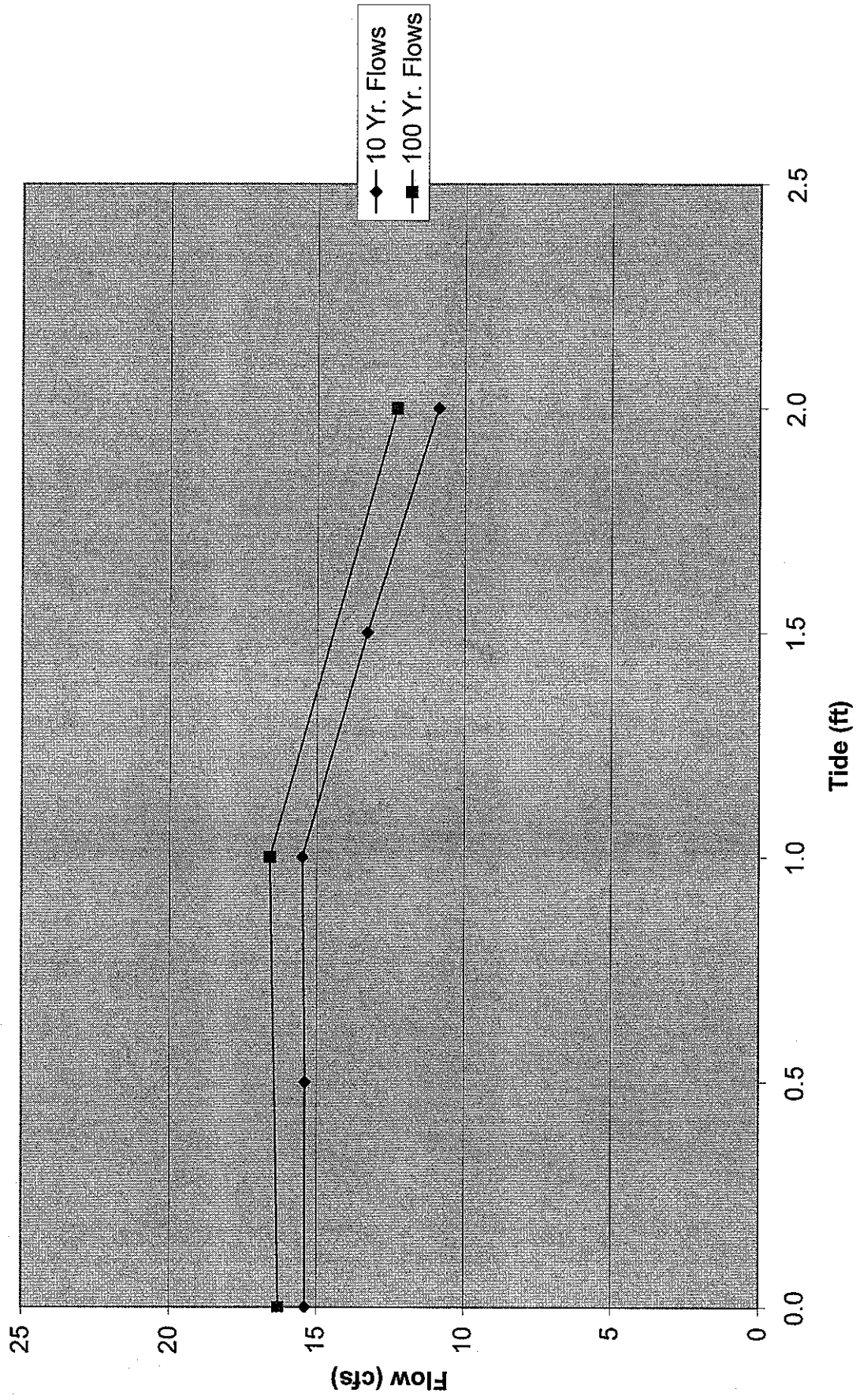
Peak Flows in Reserve Relief Canal

Legend:
- 10 Yr. Flows
- 100 Yr. Flows
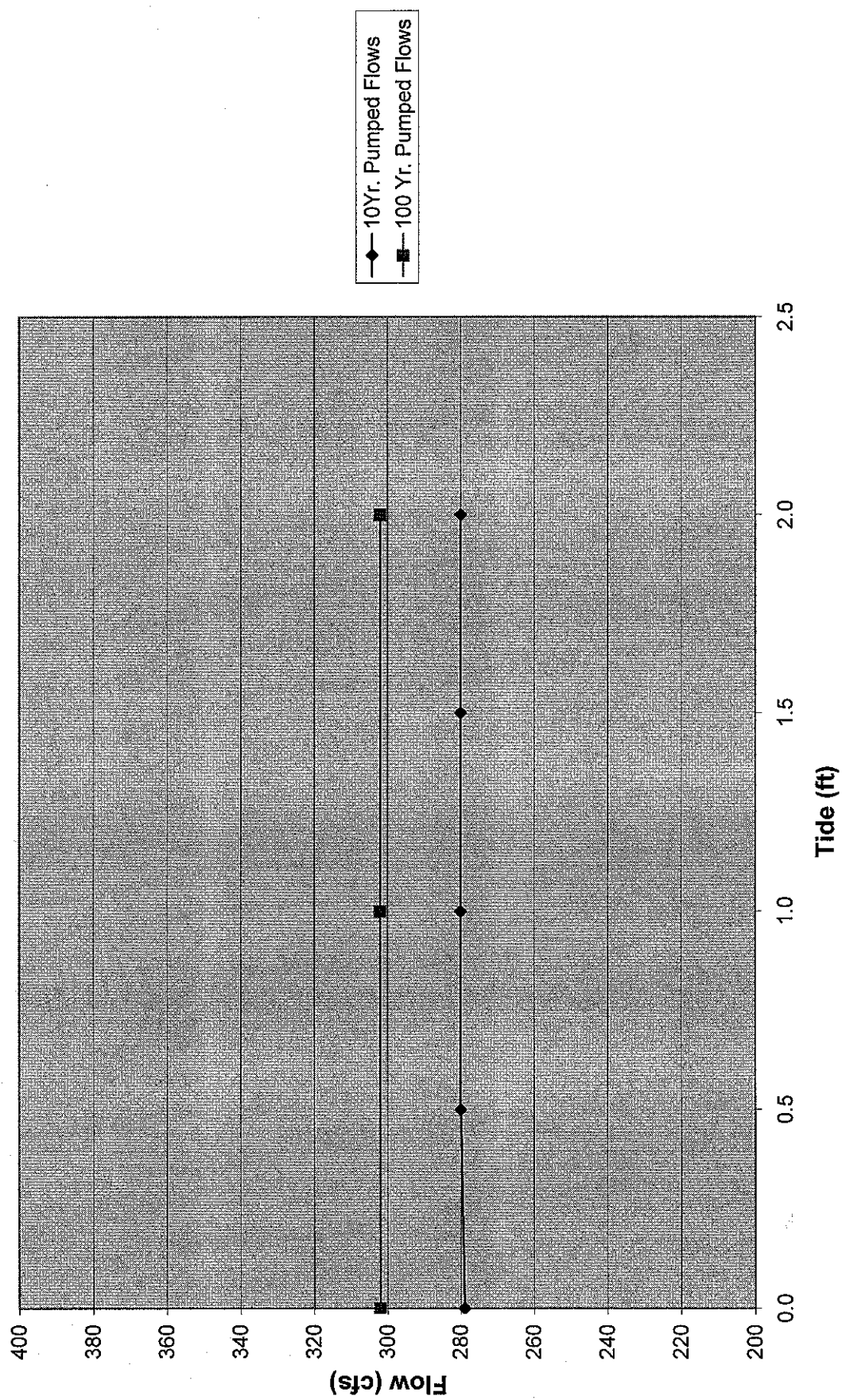
X-axis: Tide (ft)
Y-axis: Flow (cfs)
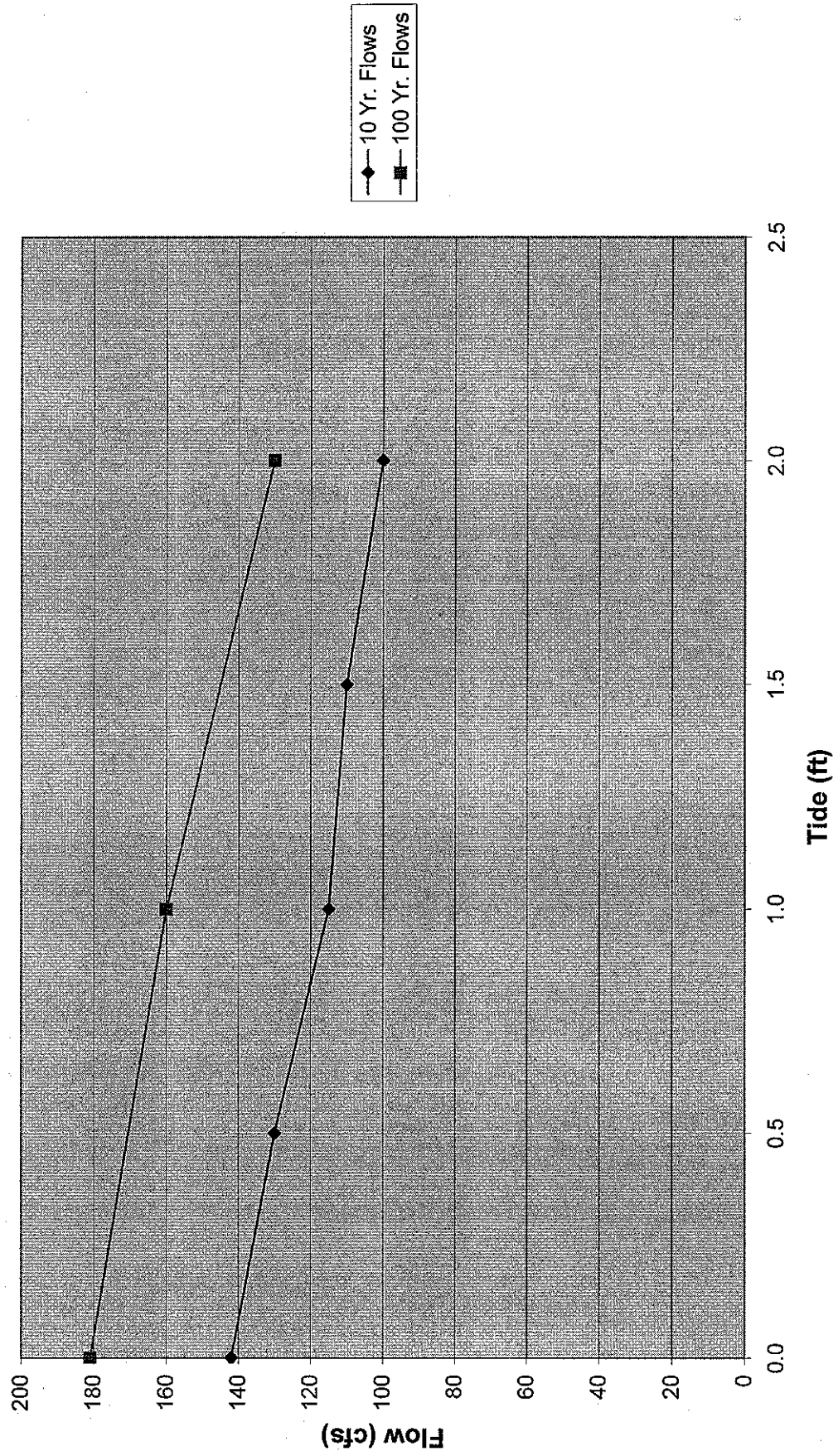
Peak Flows to Marsh 16
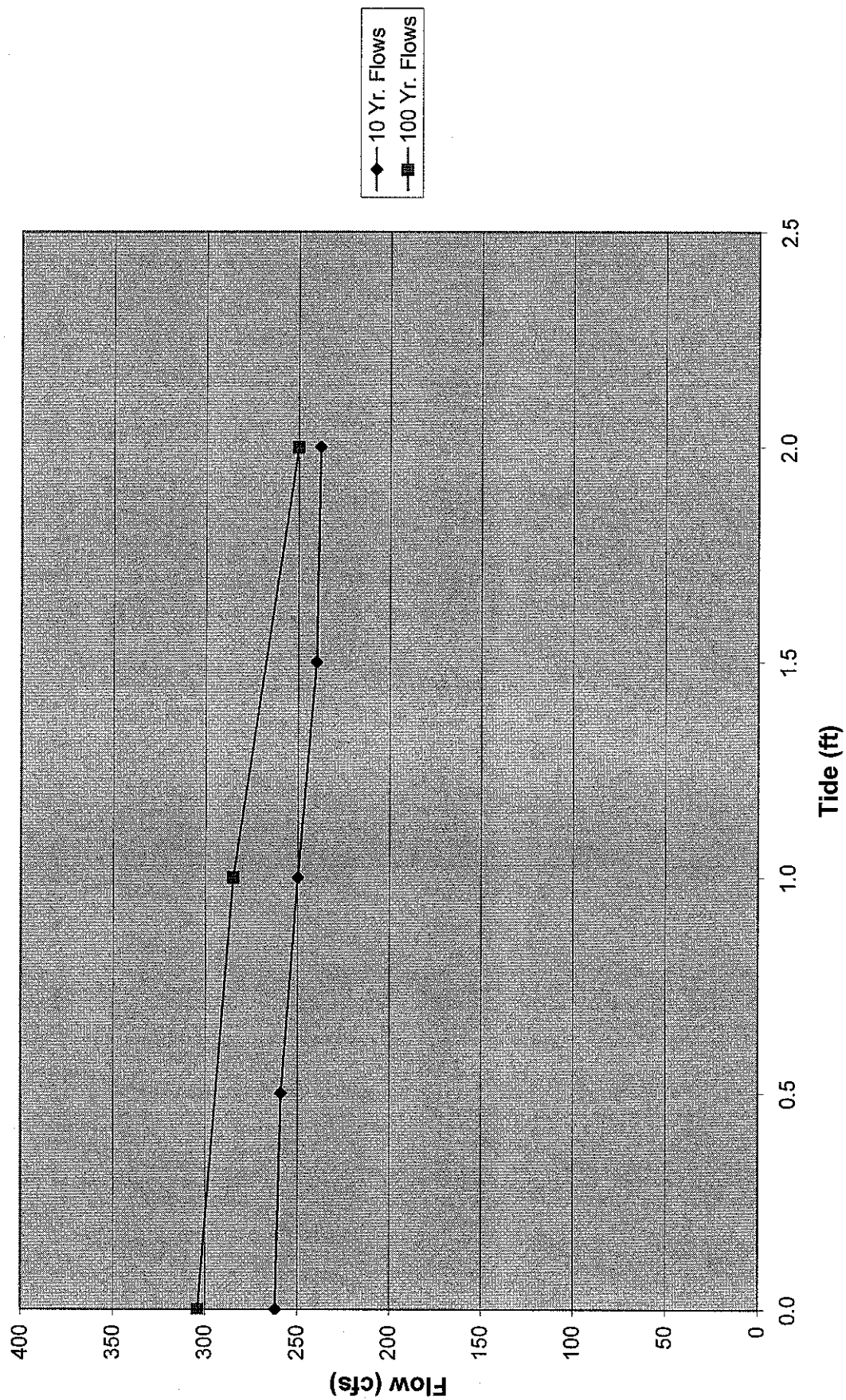
Peak Flows to Marsh 17
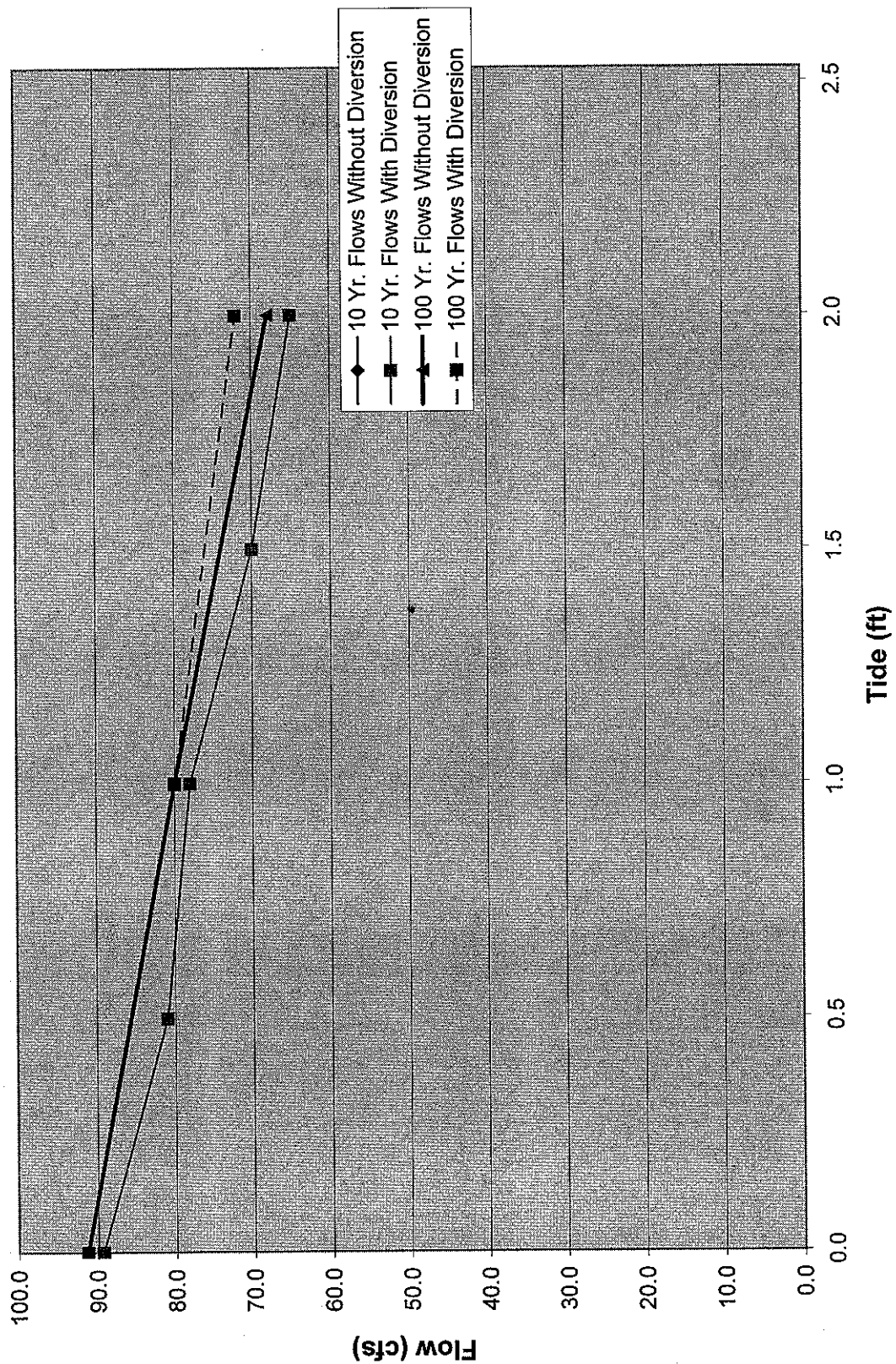
Belle Point P. S. Pumped Flows

Legend:
- 10Yr. Pumped Flows
- 100 Yr. Pumped Flows

X-axis: Tide (ft)
Y-axis: Flow (cfs)

Peak Flows to Marsh 18

Tide (ft)

Flow (cfs)

10 Yr. Flows
100 Yr. Flows